U.S. DEPARTMENT OF COMMERCE
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PB-281 506

Pretreatment of the Combined Industrial-Domestic Wastewaters of Hagerstown, Maryland. Volume I

Kappe Associates, Inc, Rockville, Md

Prepared for

Robert S Kerr Environmental Research Lab, Ada, Okla

Mar 78

PB 281 506

EPA-600/2-78-043a
March 1978

Environmental Protection Technology Series

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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SPRINGFIELD, VA. 22161

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TECHNICAL REPORT DATA
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1. REPORT NO. EPA-600/2-78-043a	2.	3. RECIPIENT'S ACCESSION NO. PB281506
4. TITLE AND SUBTITLE Pretreatment of the Combined Industrial-Domestic Wastewaters of Hagerstown, Maryland - Volume I		5. REPORT DATE March 1978 issuing date
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) David S. Kappe		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Scientific Research Division Kappe Associates, Inc. Hagerstown, Maryland 21740		10. PROGRAM ELEMENT NO. 1BB610
		11. CONTRACT/GRANT NO. 11060 EJD
12. SPONSORING AGENCY NAME AND ADDRESS Robert S. Kerr Environmental Research Laboratory -Ada, OK Office of Research and Development U.S. Environmental Protection Agency Ada, Oklahoma 74820		13. TYPE OF REPORT AND PERIOD COVERED Final Draft
		14. SPONSORING AGENCY CODE EPA/600/15

15. SUPPLEMENTARY NOTES
Appendices to Volume I can be found in Volume II (EPA-600/2-78-043b), and can be obtained through NTIS.

16. ABSTRACT
The sewage treatment plant of the city of Hagerstown, Maryland--a manufacturing city with about 130 industrial firms, which are classified in more than 25 different product categories--receives for treatment domestic sewage and a diversity of industrial waste and process waters. Some of these industrial wastewaters exert high immediate and ultimate oxygen demands that could not be satisfied by the treatment plant or were otherwise detrimental to the biological treatment processes of the treatment system. Therefore, certain methods of "pretreating" the city's combined wastewaters to render these waters more amenable to treatment by the existing treatment plant were tried and evaluated. The pretreatment methods tested were intended to assist the plant in meeting the oxygen demands by providing initial oxidation. The methods were: diffuse aeration with and without the addition of waste activated sludge, chlorination, addition of sodium nitrate, and the addition of potassium permanganate. Ammoniation was also tried in an effort to destroy some of the more noxious industrial materials in the wastewaters. Both aeration and chlorination proved to be effective methods of pretreatment, with the efficacy of aeration being enhanced somewhat by the addition of waste activated sludges. Both methods increased the BOD_5 removal efficiency of the plant under dry-weather conditions from less than 70% to better than 90%.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sludge *Sewage Treatment	Hagerstown, Maryland Combined Industrial/ Municipal *Joint Treatment* *Pretreatment*	50 B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 116
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE A06-A01

*U.S. GOVERNMENT PRINTING OFFICE : 1978 0-720-335/6075

EPA-600/2-78-043a
February 1978

PRETREATMENT OF THE COMBINED INDUSTRIAL-DOMESTIC WASTEWATERS OF HAGERSTOWN, MARYLAND

Volume I

by

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's endeavors to fulfill its mission involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured. The primary and ultimate goal of these efforts is to protect the nation from the scourge of existing and potential pollution from all sources.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report is a contribution to the Agency's overall effort in fulfilling its mission to improve and protect the nation's environment for the benefit of the American public.

William C Galegar

William C. Galegar, Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

The sewage treatment plant of the city of Hagerstown, Maryland--a manufacturing city with about 130 industrial firms, which are classified in more than 25 different product categories--receives for treatment domestic sewage and a diversity of industrial waste and process waters. Some of these industrial wastewaters exert high immediate and ultimate oxygen demands that could not be satisfied by the treatment plant or were otherwise detrimental to the biological treatment processes of the treatment system. Therefore, certain methods of "pretreating" the city's combined wastewaters to render these waters more amenable to treatment by the existing treatment plant were tried and evaluated. The pretreatment methods tested were intended to assist the plant in meeting the oxygen demands by providing initial oxidation. The methods were: diffuse aeration with and without the addition of waste activated sludge, chlorination, addition of sodium nitrate, and the addition of potassium permanganate. Ammoniation was also tried in an effort to destroy some of the more noxious industrial materials in the wastewaters. Both aeration and chlorination proved to be effective methods of pretreatment, with the efficacy of aeration being enhanced somewhat by the addition of waste activated sludges. Both methods increased the BOD_5 removal efficiency of the plant under dry-weather conditions from less than 70% to better than 90%.

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ACKNOWLEDGMENTS

This project was supported by the U. S. Environmental Protection Agency through EPA Research, Development and Demonstration Grant No. 11060 EJD, the State of Maryland and the City of Hagerstown, Maryland.

The Project Director wishes to express his deep appreciation to Mr. Harold J. Snyder, Jr., who was the EPA Project Officer at the start and through most of the project, for his much needed administrative help and to Mr. Marshall Dick, who took over the duties of Project Officer at the end of the project, for his patience and guidance in the preparation of this report.

Also, special thanks are extended to the Honorable Herman L. Mills, who was Mayor of the City of Hagerstown during the project and also the Project Grant Administrator, for his sincere interest in and steadfast support of the project program and the project team and to both Mr. Robert E. Lakin, who, as President of J. B. Ferguson and Company, had immediate responsibility for both the administrative and technical aspects of the project, and Mr. Stanley E. Kappe, President of Kappe Associates, Inc., for their invaluable guidance and engineering expertise in the design and construction of research facility and in the project studies.

Thanks are also due to Mr. James E. Eyerly, Superintendent of the Hagerstown Water Pollution Control Plant during the project, for his help in coordinating project activities at the project site and to his then assistant and the present plant Superintendent Mr. Eugene Barnhart for his outstanding assistance with the day-to-day operations and maintenance of the pretreatment facility and with the on-site analytical program, and to the laboratory technicians and plant operators of the Hagerstown treatment plant for their fine efforts in carrying out the project program plan.

It is a pleasure to acknowledge, too, Dr. Charles E. Renn, Professor Emeritus of Environmental Science Engineering, the Johns Hopkins University and Research Associate of Kappe Associates, Inc., who conducted the microscopic examinations of the plant biota, and Mr. Dick C. Heil, Mr. Neil F. Kershaw and Mrs. Julia M. Patel, engineer and chemists, respectively, of Kappe Associates, Inc., their exceptional engineering and analytical contributions to the project.

In addition, the Project Director wishes to thank the industries that were surveyed under the project for their superb cooperation and participation in the survey effort.

SECTION I

INTRODUCTION

A. Statement of the Problems and Objectives of Study

The City of Hagerstown, Maryland, with a population of over 35,000 persons, is the seventh largest municipality in the state of Maryland. It is a manufacturing city with about 130 industrial firms, which are classified in more than 25 different product categories. These industries produce such diverse products as aircraft, trucks, pipe organs, furniture, food products, chemicals, dyed textiles, electrical equipment, tools and toys.

Thus, the Hagerstown Water Pollution Control Plant, which serves not only the city proper but also contiguous areas, receives in addition to domestic sewage a diversity of industrial waste and process waters. Some of these waters exert high immediate and ultimate oxygen demands that could not be satisfied by the existing treatment plant or were otherwise detrimental to the biological treatment processes of the plant. Consequently, the Hagerstown treatment plant experienced great difficulty in achieving wastewater treatment to the degree necessary to meet the requirements established by the Maryland Department of Health and the Maryland Department of Water Resources. Although the plant uses the contact stabilization form of the activated sludge process--which in theory ought to be able to reduce the pollutional strength of the raw wastewaters in terms of BOD by at least 85%--it typically achieved BOD_5 removals in the range of only 40 to 60 percent.

From time to time, over a period of many years, treatment plant personnel and various consulting engineering firms called in by the city conducted at best cursory investigations to ascertain the specific causes of the Hagerstown wastewater treatment problems. Their findings strongly suggested that the industrial wastewaters that were the most harmful to the treatment plant were those from the metal plating plants and textile dyeing plants. Moreover, most, if not all, of these investigators strongly suspected that certain substances in these particular industrial wastewaters exhibited inhibitory and even toxic effects on the biota of the treatment plant. It was reported by one team of investigators who carried out a fairly extensive survey of the industries in the city that the following noxious and toxic substances were being discharged into the city's sanitary sewage system and reaching the treatment plant in sufficient concentrations to be especially troublesome:

1. Napthols--water insoluble azo dyes, which act as strong disinfectants.

2. Sodium hydrogen sulfite--a strong reducing agent, which can readily react with dissolved oxygen and therefore exert an immediate oxygen demand. It is used in textile dyeing as an antichlor, primarily.

3. Sodium hydrosulfite (sodium dithionite)--a reducing agent that is stronger than sodium hydrogen sulfite. It is used in textile dyeing as a dye stripping agent and bleach.

4. Sulfonated organic compounds--dyes and detergents.

5. Sulfoxylates--strong reducing agents, which like sodium hydrosulfite are used as stripping agents in textile dyeing.

6. Reduced chemical dyes--complex organic compounds that, reportedly, are readily oxidized and require considerable amounts of oxygen for treatment.

7. Chromate metallic dyes.

8. Petroleum solvents.

9. Miscellaneous chemicals--sulfuric acid, hydrochloric, acetic acid and formaldehyde.

Daily tests taken by the laboratory personnel of the treatment plant had indeed shown that "free sulfites", which ideally should not be present at all in the raw wastewaters, entered the plant on week days in concentrations that generally ranged from 4 to 200 mg/l and occasionally reached as high as 450 mg/l. Sulfites were usually not found in the wastewater on either Saturdays or Sundays; and, it was noted that the variations of sulfite concentrations during week days followed no regular pattern.

Although the plant consistently failed to produce an effluent of acceptable quality, the most noticeable plant operational problem--which subjected the city government, the city engineer and plant management personnel to much public criticism--was the continual production by the plant of offensive odors, in particular, the pungent, "rotten-egg" odor of hydrogen sulfide gas. Frequently, the concentration of hydrosulfuric acid, H_2S, in the plant effluent would be found to be as high as 10 mg/l, and hydrogen sulfide gas would emanate from the primary tanks and would be swept from the aeration tanks in amounts sufficient to annoy the entire population of the City of Hagerstown, as well as people of surrounding communities.

As a result of a great public outcry, efforts were made by plant personnel to minimize the generation of this odoriferous gas in the aeration basins by maintaining mixed liquor suspended solids concentrations in the contact aeration tanks at very low levels (500 to 900 mg MLSS/l) and to check production of the gas by constant chlorination of the return sludges and the mixed liquors themselves. Unfortunately, however, these efforts were only partially successful in abating odors and, of course, did not improve the wastewater treatment efficiency of the treatment plant.

In another effort to minimize treatment plant problems, key officials of the textile dyeing plants that discharged into the city's sewage system were contacted by representatives of the city and meetings between the city representatives and the dye plant officials were held to inform the dye plants officials of the difficulties being experienced by the treatment plant and to solicit their aid in abating the discharge of noxious and toxic dyeing wastes into the city's sewers. Consequently, the dye plants agreed to cooperate and to take certain corrective steps. Unfortunately, however, no significant improvement in conditions at the treatment plant was ever noted as a result of these meetings.

Also at these meetings, it was suggested that the dyeing plants should treat their wastes before the wastes are discharged into the sewerage system; but, it was quickly pointed out by the dye plant officials that most of the dyeing plants are located well within the city and, have limited, if any, space for expansion and that the possibility of them constructing waste pretreatment systems therefore was rather small.

Consequently, in May 1967, the city formulated a research program to study through a full-scale project various methods of actually pretreating the city's combined industrial-domestic wastewaters at the site of the municipal treatment plant itself and, subsequently, applied to the Federal government for financial assistance. In March 1968, the city received from the Federal Water Pollution Control Administration a Federal Research and Development Grant, WPRD 149-01-68, of $320,890 or 75% of eligible project costs, whichever was less. This grant was then supplemented by a state grant covering 12.5% of project costs eligible for coverage under the Federal grant. The project costs eligible for Federal participation equalled the total project cost of $427,853.

B. General Study Plan

The object of the project was to study and evaluate certain pretreatment methods aimed at rendering the city's combined industrial-domestic wastewaters more amenable to the existing conventional biological treatment processes of the city's wastewater treatment plant. Since the combined wastewaters regularly exerted high immediate and ultimate oxygen demands, five of the six pretreatment methods that were studied were methods intended to assist the existing treatment plant in meeting these oxygen demands by providing initial oxidation. The five pretreatment methods were diffuse aeration with and without the addition of waste activated sludge, chlorination, sodium nitrate addition, and potassium permanganate addition. Ammoniation was the sixth pretreatment scheme that was studied. It was hoped that ammonia would prove to be effective in destroying some of the more noxious industrial materials contained in the wastewaters.

As planned, these pretreatment methods were studied in pairs to conserve project time and were applied to the raw wastewaters as these wastewaters flowed through a pretreatment facility built especially for the research project on the grounds of the Hagerstown Water Pollution Control Plant. This facility, which was designed to handle the city's entire wastewater flow, was constructed between the grit chamber and the primary settling tanks of the municipal treatment plant. The facility consists of two aeration tanks, a mechanical building for housing the necessary facility equipment and the facility equipment.

At the design flow for the treatment plant, the facility aeration tanks each hold 300000 gallons (40000 ft^3) of wastewater and together, a total of 600000 gallons (80000 ft^3) of wastewater. Air can be supplied to the two tanks by either or both of two positive displacement type blowers, each having a capacity of 3500 cfm. These blowers are a part of the facility equipment and were purchased with project funds. The aeration tanks with their air supplies were intended not only for aerating the wastewaters as called for in the project plan but also for mixing the wastewaters with the selected chemical additives that were tested under the various study tasks of the project.

Facility equipment also include a dry chemical feeder for feeding sodium nitrate and potassium permanganate and a gas feeder for feeding ammonia and chlorine. By means of a valve-and-piping system, these feed machines were able to deliver aqueous solutions of the various chemical additives used in the project to the influent ends of one or the other or to both of the two aeration tanks of the facility.

Also among the equipment of the facility are an electronic wastewater quality monitoring system that was able to measure and record continually the pH, dissolved oxygen concentrations and oxidation-reduction potentials of the raw wastewaters and of the effluents of the two aeration tanks and three automated and refrigerated samplers that collected proportionally to the flow composite samples of the raw wastewaters and the two aeration tank effluents.

The pretreatment facility was constructed with two aeration tanks so that, as mentioned, two pretreatment methods could be studied at the same time. As the wastewater flow passed through the influent channel of the research facility, it was divided into two separate flows for separate treatment. Beyond the project facility, the treatment plant itself was modified as called for under the research program, to enable this flow separation to be maintained. Thus, the existing treatment plant beyond the facility functioned essentially as two independent and distinct secondary treatment systems, whose responses to the pretreatment methods being employed could be examined. However, it should be noted that since two studies were always conducted simultaneously with the plant divided, one plant division never functioned as the experimental "control" for the other.

The original project program plan provided 4 months for the design of the project facility, a month and a half for bidding and letting of the construction contract and nine and one half months for facility construction. In addition, nine months after the project was initiated and concurrent with project facility construction, the program plan scheduled five months for the acquisition of necessary laboratory equipment, training of laboratory personnel and establishment of analytical procedures. For a three-month period starting twelve months after project initiation, the plan called for extensive analyses of the wastewaters entering, passing through and leaving the Hagerstown plant in order to gather good information on wastewater characteristics and treatment plant performances. Once the construction of the project facility was completed and the baseline analyses were finished, the project plan called for the treatment facility to be brought into service and tested and its aeration tanks allowed to stabilize for one month. Then, the various pretreatment methods were to be studied in pairs, each pair being tried over a two-month period with two weeks allotted after each study (except the last, of course) for the incoming raw sewage to pass through the pretreatment tanks with only plain aeration to flush out the tanks for the next study and to allow time for process "change over."

After the various pretreatment methods were tried and evaluated, that method that yielded the best results then was to be studied further, for an additional two months; but, this time, the study was to be done with pretreatment method being applied to the entire wastewater flow and with the secondary systems of the treatment plant recombined so that the plant beyond the pretreatment facility would function as a single unit as it had before the pretreatment studies were begun.

Also included in the project program plan was a survey of certain select industries within the city--industries that were suspected of being possible sources of the more noxious and toxic wastes that the treatment plant was receiving. On the basis of the assumption that most of the noxious and toxic wastes were contributed by the textile dyeing plants, these plants, in particular, were considered of primary interest and, therefore, were the main concern of the planned survey. This survey was scheduled to begin one month after the start of the project and to end seven months later.

Except for delays in construction of the project facility and in the construction of an additional final settling tank for the treatment plant and modification of two existing final settling tanks (work not done under the program of the research project) and extensions of a pretreatment study and the industrial survey periods, this project schedule and plan was essentially adhered to. The project program tasks and the actual periods over which they were carried out are as follows:

Period	Project Task
5/22/68 - 10/1/68	Site studies and design of project facility.
10/1/68 - 12/11/68	Review of facility plans and specification by state and federal agencies.

Period	Project Task
12/23/68 - 1/30/69	Construction of project facility and modification of treatment plant piping to achieve two separate secondary treatment systems.
8/1/68 - 9/31/70	Survey of industrial plants.
10/1/68 - 7/15/69	Preparation of treatment plant laboratory for analytical program of the project, training of laboratory personnel, and establishment of analytical procedures.
7/15/69 - 5/19/70	Execution of baseline studies--analysis of treatment plant wastewaters.
1/27/70 - 5/19/70	Startup of project facility, stabilization of the aeration tanks of the facility, and installation and calibration of the facility wastewater quality monitoring system.
5/19/70 - 7/24/70	Investigation of wastewater pretreatment by plain aeration and by aeration with addition of waste activated sludge.
7/24/70 - 8/18/70	Preparation for the next pair of pretreatment studies.
8/18/70 - 10/15/70	Investigation of wastewater pretreatment by addition of ammonia and by addition of sodium nitrate.
10/15/70 - 10/31/70	Preparation for next pair of pretreatment studies.
10/31/70 - 12/25/70	Investigation of wastewater pretreatment by addition of chlorine and by the addition of potassium permanganate.
12/25/70 - 1/18/71	Preparation for final pretreatment studies--recombination of in-plant wastewater flows.
1/18/71 - 3/23/71	Application of pretreatment by chlorination, to entire raw wastewater flow.

Period	Project Task
2/20/71 - 1/16/71	Loading of specially prepared digestor with combined sludges and digestion of sludges for sludge dewatering studies.
4/1/71 - 4/7/71	Studies on dewatering of digested sludges and waste activated sludge on a pilot vacuum filter.
4/15/71 - 4/21/71	Studies on dewatering of digested sludges on an existing sand bed.
4/21/71	Supplementary analyses and data tabulation.

SECTION II

CONCLUSIONS

From May 22, 1968, to April 21, 1971, the City of Hagerstown, Maryland, investigated six proposed schemes of pretreating its combined domestic-industrial wastewaters. These schemes or methods, which, during the investigation, were applied to the city's raw wastewaters at the site of the city's wastewater treatment plant, were pretreatment by plain aeration, aeration with the addition of waste activated sludge, ammoniation, chlorination, addition of potassium permanganate, and addition of sodium nitrate. It was hoped that one or more of these methods would be effective in significantly increasing the rather poor degree of treatment the existing plant was able to achieve and in eliminating the frequent evolution from the plant of the malodorous gas hydrogen sulfide.

During the project, it was found that the plant suffered from (1) hydraulic overloading during wet-weather conditions as a result of the considerable susceptibility of the city's sanitary sewage system to stormwater inflow, (2) organic overloading occurring regularly on week-day mornings as a result of batch discharges of cottage cheese whey from a local food processing plant and (3) the frequent presence in the raw wastewaters of dye stripping agents (which exerted high immediate oxygen demands) and intensely colored dye stuffs from local textile dyeing plants.

The hydraulic and organic overloads were overwhelming in their impacts on the treatment plant and were obviously the major causes of the treatment difficulties the facility was having. In addition, it is believed that, because of their overwhelming nature, the two types of overloads could have easily obscured other factors contributing to the poor treatment performance of the plant. Moreover, they interfered greatly with several of the pretreatment studies of the project, particularly the hydraulic overloads as they varied widely in their magnitudes and in the times and extents of their occurrences.

Even so, it was definitely determined that there were not present in the municipal wastewaters, at least in effective concentrations, any materials that were toxic or inhibitory to the treatment plant biota, Thus, contrary to the opinions expressed by certain previous investigators, the biological processes of the plant were not being affected by bacteriocidal or bacteriostatic substances in the wastewaters.

During the base-line studies of the investigation, it was discovered, too, that among the biota of the treatment plant there was an appreciable population of a filamentous sulfur organism, which, it is concluded, markedly affected the settleability of the mixed liquor suspended solids and contributed appreciably to the high-solids carry-over into the final plant effluent that the plant had been experiencing for some time. This bacterial population, however, was subsequently eliminated from the plant, in the pretreatment studies, through the preaeration of the raw wastewaters.

Other conclusions that were drawn from the results of the investigation, in particular the pretreatment studies themselves, are as follows:

1. Pretreatment of the municipal wastewaters by plain aeration, by aeration with the addition of activated sludge, and by chlorination were effective in improving the degree of wastewater treatment achieved by the treatment plant.
2. Preaeration of the municipal wastewaters effectively reduced the evolution of hydrogen sulfide gas from the treatment plant and produced a better settling biological floc in the secondary system by essentially eliminating from the aeration tank biomasses the above mentioned population of the filamentous sulfur bacterium.
3. Pretreatment of the municipal wastewaters by addition of sodium nitrate lead to the floatation (assumably through denitrification) of raw primary and waste activated sludges deposited in the primary settling tanks of the treatment plant and, in addition, may have stimulated the growth of a hitherto unidentified filamentous organism that appeared in such great abundance during the application of this method that the settleability of the solids in the aeration tanks and in the anaerobic digesters of the plant were considerably impaired.
4. Pretreatment by addition of ammonia may have improved plant performance somewhat; but, the experimental data are inconclusive as a consequence of the fact that the plant, during much of the time period devoted to the study of this method, was upset by severe hydraulic overloading.
5. No noticeable benefits were obtained by pretreatment with potassium permanganate; however, it is felt that the dosages applied were minimal and that higher dosages should have been tried.
6. Pretreatment by chlorination increased color removal but only at the higher chlorine dosages used in the pretreatment study. The other pretreatment methods were not noticeably effective.

In addition, it is also concluded that, by the combination of substantial reduction of stormwater inflow into the city's sewerage system, application of pretreatment by plain aeration with the addition of waste activated sludge and flow equalization over 24 hours of the slug discharges of the cheese whey from the food processing plant, the Hagerstown Water Pollution Control Plant should be able to achieve BOD_5 removals of 90% or better.

SECTION III

RECOMMENDATIONS

Based on the experimental data and conclusions of this project, the following recommendations are offered:

1. The inflow of stormwater into the city's sanitary sewerage system should be substantially reduced.

2. The batch discharge into the sanitary sewerage system of significant amounts of high pollutional strength wastes, noxious materials, and/or bacteriocidal or bacteriostatic substances should be prohibited; and, the installation of aerated waste flow equalization tanks by industries currently practicing batch discharging of appreciable volumes of wastewaters should be strongly encouraged.

3. Pretreatment of the municipal wastewaters by plain aeration, or by the combination of aeration and the addition of waste activated sludge, or by chlorination should be practiced.

4. Pretreatment of the municipal wastewaters by addition of sodium nitrate should definitely not be employed because of its adverse effects on the municipal treatment plant.

5. The use of other oxidants, such as ozone, pure oxygen and hydrogen peroxide, for pretreatment should be explored; and, the method of pretreatment with potassium permanganate should be tried with higher permanganate dosages.

SECTION IV

THE PROJECT SITE--THE HAGERSTOWN WATER POLLUTION CONTROL PLANT--AND THE PROJECT FACILITY

A. Description of the Hagerstown Water Pollution Control Plant

The Hagerstown Water Pollution Control Plant is located on a 300-acre farm in the southeastern part of the City of Hagerstown and receives the wastewaters not only from the city but areas surrounding the city. It serves a population estimated to be about 43500 people. The plant is of the conventional activated sludge type with a design average hydraulic load capacity of 7.5 mgd. However, in an effort to effect better treatment, it now employs the contact stabilization modification of the conventional activated sludge process. Its treated effluent discharges into Antietam Creek, a major tributary of the Potomac River.

The original municipal treatment plant was constructed in 1924. Over the years, as the city grew, the plant was improved and expanded. Today, the plant (exclusive of the project facility) and the city's sewerage system consist of the following units:

1. Outfall Sewer

A 54-inch reinforced concrete box sewer serving a separate sanitary sewerage system laid throughout the confines of the city limits and contiguous areas in Washington County. The capacity of the 54-inch outfall is approximately 25.0 mgd.

2. Grit Removal Facilities

The existing grit removal facilities of the plant consist of two grit chambers; one is a gravity type and the other, an aerated type.

The gravity type grit chamber is 18'-0" x 18'-0" x 1'-6" normal water depth with 2'-0" maximum water depth and is equipped with a circular grit collector and other mechanical means for removing grit from the unit. The volume at 1'-6" depth is 488 ft^3 (3640 gal) to give a detention time of 0.88 minutes at 6.0 mgd; the volume at 2'-0" depth is 648 ft^3 (4850 gal) to give a detention time of 0.58 minutes at 12.0 mgd flow. Because this grit chamber does not give satisfactory operating results, it is presently not used except as a stand-by unit.

The aerated grit chamber, which has mechanical conveyor equipment to remove the grit from the tank for disposal into a truck, is 18'-0" long x 16'-0" wide x 12'-8" water depth at a flow rate of 12.0 mgd. The detention time that this chamber provides at 12.0 mgd flow is 3.25 minutes.

3. Screen and Comminutor

A manually cleaned coarse bar screen with 3-inch clear openings is installed in the 54-inch outfall sewer ahead of the grit chambers to catch and remove the heavy trash.

On the downstream side of the grit chamber, there is a Chicago Pump Model 25A comminutor to cut up all coarse material in the sewage. This machine has a capacity to handle wastewater flows from 1.5 to 25.0 mgd.

4. Primary Settling Tanks

The plant has two rectangular primary settling tanks, each being 75'-0" x 16'-0" with a 10'-0" water depth, which have a combined volume of 179500 gallons and one circular primary settling tank, which is 55'-0" in diameter with a 10'-0" side water depth and a 2'-3-1/2" deep hopper bottom and has a volume of 178000 gallons. The plant, therefore, has a total primary settling volume of 357500 gallons. Each rectangular tank has a surface area of 1200 ft^2 and the circular tank a surface area of 2380 ft^2 for a total settling area of 4780 ft^2. Furthermore, each rectangular tank has a weir length of 16 ft and the circular tank has a weir length of 173 ft to give a total weir length of 205 ft.

5. Aeration Tanks

There are in the plant six spiral-flow aeration tanks in two batteries of three tanks each. Each tank is 122'-0" x 16'-0" x 15'-0" water depth, providing a volume of 29280 ft^3/tank, 87800 ft^3/battery or a total of 175680 ft^3 for the six tanks. In addition, the plant has a battery of two spiral-flow aeration tanks, each being 95'-0" x 30'-0" x 15'-0" water depth with a 42750 ft^3 volume. The total volume provided by eight aeration tanks is therefore 261180 ft^3.

Of the six tanks constructed in two batteries of three tanks, each tank has a double row of air diffuser tubes along one side and four transverse wood baffles that divide the tank into five equal volume sections and extend from above water surface to within one foot of tank bottom to reduce short circuiting. Each aeration tank of the two tank battery has air diffusion tubes mounted 2'-0" above the tank bottom in two rows on 4-inch air headers suspended from six "swing-diffuser" assemblies.

Although originally designed for the conventional activated sludge process, the two batteries of three aeration tanks per battery and the battery of two aeration tanks are operated in the contact stabilization mode. The aeration tanks of each three-tank battery are employed in series with return activated sludge being discharged into the head end of the first of the three tanks in the series and primary effluent being introduced into the head end of the third or last tank in the series. Thus, in each three tank battery, the first two tanks function as sludge reaeration tanks while the third tank functions as a contact aeration basin. In the one battery of the two aeration tanks, one of the two tanks serves as the sludge aeration tank, and the other, as the contact aeration tank.

The return sludge to both of the three tank batteries is a combination of the settled activated sludges from the three settling tanks that follow the two batteries. The return sludge to the two tank battery is taken from the one settling tank that follows this battery.

6. Final Settling Tanks

The flow from the battery of six aeration tanks is conveyed to two square settling tanks and one circular settling tank which was built during the construction of the project facility and brought into use just before the beginning of the first pair of pretreatment sludges. Each square settling tank is 50'-0" x 50'-0" x 10'-0" side water depth with 3'-0" hopper depth and is equipped with a circular type collector system. Each tank has a center feed well and two weir troughs extending across the tank and one weir plate along a side. And, each tank has a surface area of 2500 ft^2, a volume of 195000 gallons and a weir length of 247 ft. The single circular settling tank is 55'-0" in diameter x 10'-0" side water depth and is equipped with a suction type sludge collector. The tank has a surface area of 2380 ft^2, a volume of 178,000 gallons, and a weir length of 173 ft.

The flow from the battery of two aeration tanks is conveyed to one circular final clarifier tank which is 60'-0" in diameter with a 11'-0" side water depth and a 2'-4-3/8" deep hopper bottom. The tank is equipped with a circular sludge collector, which moves sludge to sump located in center of tank. The tank has a volume of 31100 ft^3, a surface area of 2827 ft^2 and a weir overflow length of 188 ft.

Together, all the final settling tanks of the treatment plant have a total surface area of 10200 ft^2, a total volume of 822,000 gallons and a total weir length of 855 ft.

7. Chlorine Contact Tanks

There are two chlorine contact tanks, each being 61'-0" x 44'-0" x 5'-0" water depth and having five dividing walls or baffles to form end around flows in the 44-foot direction. Each tank has a volume of 100650 gallons to give a total volume for chlorination of 201300 gallons. These tanks are rather recent additions to the treatment plant system. They were, in fact, constructed during the baseline study period of the research project and were not brought into service until well after the pretreatment studies of the project were initiated.

8. Sludge Thickening

Sludge from the primary tanks, which is a mixture of waste activated and raw sludges, is thickened before going to the digesters in a tank which is 20'-0" in diameter x 10'-0" deep and equipped with a Dorr picket-fence type mechanical thickener. The volume of the tank is 3140 ft^3.

9. Sludge Digestion Tanks

Sludge from the thickening tank is pumped to one of five digesters. Four of the digesters are heated by hot water circulated through coils installed in the digesters and are mixed by gas recirculation. The remaining digester is not heated or covered. It is used as a sludge storage tank and is provided with a small aeration system for mixing and scum breaking.

The capacities of these tanks are as follows:

Digester No. 1 (Primary) - 53015 ft^3
Digester No. 2 (Secondary) - 49088 ft^3
Digester No. 3 (Storage) - 53015 ft^3
Digester No. 4 (Primary) - 53015 ft^3
Digester No. 5 (Secondary) - 49088 ft^3

The total capacity of all the digesters, excluding Digester No. 3, is ft^3; the total capacity of all the digesters, including Digester No. 3, is 257221 ft^3.

Digesters No. 1 and No. 4 are 50'-0" diameter x 24'-6" side water depth x 5'-9" hopper depth and are provided with fixed steel covers. Digesters No. 3 and No. 5 are 50'-0" diameter x 22'-6" side water depth x 5'-9" hopper depth and are provided with gas storage type floating steel covers. Digester No. 3 is of same size as Digesters No. 1 and No. 4. As mentioned, it is open and serves as a sludge storage tank as well as a digester. Sludges are normally pumped to Digester No. 1 with overflow to Digester No. 2 and from there to Digester No. 3, or into Digester No. 4 with overflow into Digester No. 5 and from there to Digester No. 3.

10. Sludge Drying Beds

Although most of the digested sludges are carted away by tank trucks for disposal on farm lands, the treatment plant has four open sludge drying beds, each 90 ft x 26 ft, and six beds, each 121 ft x 47 ft, enclosed by a structure having a steel roof and open sides. The total drying bed area is 43482 ft^2.

11. Return Sludge Pumps

The sludges from the two 50-foot square and the one 55-foot diameter circular clarifiers are pumped by either one or both of two 1900 centrifugal pumps to the battery of six aeration tanks, through two 8" discharge lines.

The sludge from the 60-foot diameter circular clarifier is pumped by either one or both of two 950 cfm centrifugal pumps to one aeration tank of the battery of two aeration tanks.

All pumps are provided with constant speed motors and the rates at which sludges are returned are controlled by throttling gate valves in the discharge lines of the pumps. Total return sludge capacity of the plant is 5700 gpm or 6.1 mgd with all pumps operating.

12. Blowers

Air requirements are furnished by the following equipment:

(1) One Roots-Connersville two speed positive displacement type blower with maximum capacity of 2562 cfm (1900 cfm at 695 rpm, 2562 cfm at 870 rpm);

(2) Two Ingersoll-Rand Centrifugal blowers, each rated at 1500 cfm to 3000 cfm; and,

(3) One Chicago Standardaire two speed positive displacement blower with maximum capacity of 1600 cfm (900 cfm at 1150 rpm, 1600 cfm at 1750 rpm).

The air lines are interconnected so that air from all blowers can supply all aeration tanks.

B. Capacities of Existing Sewage Treatment Units

1. Grit Chambers

Each grit chamber is designed for a capacity of 12.0 mgd; thus, both units together have a maximum capacity of 24.0 mgd.

2. Comminutor

The comminutor is rated for a maximum capacity of 25.0 mgd.

3. Primary Settling Tanks

At 10.0 mgd flow, these tanks provide a detention time of 51.5 minutes, a surface settling rate of 2100 gals/ft^2/day and a weir overflow rate of 48800 gals/ft/day.

4. Aeration Tanks

With a total volume of 1950000 gallons and based on mixed liquor suspended solids concentration in the aeration tanks of 3500 mg/l and loading of 35 lbs BOD_5 per 100 lbs solids, the organic load capacity of aeration tanks is:

$$\frac{\text{lbs } BOD_5}{\text{day}} = 1.95 \text{ mgd} \times 3500 \text{ mg/l} \times 8.34 = 19850 \text{ lbs/day}$$

Assuming Average BOD_5 of 225/mg/l, the waste flow yielding the above loading would be

$$\text{Flow} = \frac{19850}{8.34 \times 225} = 10.6 \text{ mgd}$$

The detention time in the aeration tanks at 10.0 mgd flow would be 4.68 hours. (The detention time at design flow, 7.5 mgd, is 6.2 hours.)

5. Final Settling Tanks

Based on surface settling rate of 1000 gals/ft^2/day, the settling tanks can handle 10.2 mgd per day, providing a detention time of 1.93 hours and a weir overflow rate of 11930 gals/ft/day.

6. Chlorine Contact Tanks

The volume of 201300 gallons at 30-minute detention time provides sufficient capacity to handle an average flow of 9.67 mgd.

7. Sludge Digestion

Since high rate digestion by gas recirculation is rated at 2.0 ft^3 per capita, the four anaerobic digesters with a total volume of 204206 ft^3 can handle a total equivalent population of 102103 persons. Therefore, even without the digester/storage tank, the digester capacity of the treatment plant is more than adequate.

8. Sludge Drying Beds

Sludge drying beds rated at 1.5 ft^3 per capita and having an area of 43482 ft^2 can handle an equivalent population of 29000 persons and with tank truck disposal as the major method of disposing the sludge, sludge bed capacity is adequate to serve during weather periods when tank truck disposal is not possible.

C. Project Modifications of the Hagerstown Water Pollution Control Plant

In order to be able to carry out two pretreatment studies at the same time in accordance with the project program plan, it was necessary to have the effluents from the two aeration tanks of the pretreatment facility fed separately to two independent treatment systems--each system having its own primary and secondary units and distinct sludge return systems. Because of the layout of the Hagerstown plant, the dividing of the plant into two separate treatment systems required only minor changes in the piping arrangement of the plant.

Specifically, the following changes were made in the treatment plant piping system:

The concrete wastewater distribution box that precedes the primary settling tanks of the treatment plant was hydraulically connected to the longitudinally divided effluent channel of the pretreatment facility and sectioned by means of a simple, transite divider wall into two compartments. The sectioning was done in a manner such that in the box the effluent from one pretreatment tank (referred as pretreatment Tank A) would flow to and be distributed between the two rectangular primary settling tanks and the effluent from the other pretreatment tank (pretreatment Tank B) would flow into the circular primary settling tank of the treatment plant.

The piping for the circular primary tank effluent was changed to enable this effluent to be conveyed directly to the contact aeration tank of the two-aeration-tank battery; and the piping for the rectangular primary tank effluents was modified so that these effluents would flow to only the contact aeration tanks of the two three-aeration-tank batteries. Originally, the effluent of the circular primary tank was combined with the effluents from the rectangular settling tanks; and, then, the combined primary effluent flow was distributed among the three contact stabilization tanks of the treatment plant.

No further piping changes were necessary in the existing plant since the wastewater flow entering the two three-tank batteries and the flow entering the one two-tank battery are not combined until the treated wastewaters are finally discharged to the receiving stream and since the return sludge systems of the two groups of aeration tanks were already separate systems.

As a result of these few piping changes, the plant was able to function as two distinct and independent treatment systems. The two distinct treatment systems thus formed are referred to herein as Systems A and B and were comprised of these treatment plant units:

Treatment System A	Treatment System B
1. Pretreatment Tank A.	1. Pretreatment Tank B.
2. The two rectangular primary settling tanks.	2. The circular primary settling tank.
3. The two three-aeration-tank batteries.	3. The battery of two aeration tanks.
4. The two square and the 55-foot diameter circular final settling tank.	4. The 60-foot diameter circular final settling tank.

D. Project Facility

1. Design of the Project Facility

Immediately after the initiation of the research project, certain preliminary engineering studies of the project site were made to secure those site data needed to design and to integrate structurally and hydraulically the project facility into the existing Hagerstown treatment plant. A survey crew gathered data on pertinent ground elevations and invert elevations of existing pipe lines, channels, and junction and distribution boxes. These data then were used to prepare a preliminary site plan showing the critical invert elevations and site topography. On the basis of the survey data and prepared site plan, engineering determinations were made as to the best location for the two pretreatment tanks and the facility influent and effluent conduits; and, subsequently, preliminary plans of the project facility were developed.

The plans that were generated called for the aeration tanks of the facility to be located between the existing comminutor chamber and the concrete division box that distributes the wastewater to the primary settling tanks of the plant. It was known, however, that the hydraulic head differential between the chamber and the box was rather small; but, it was not known for certain how small. Consequently, to ensure that accurage design data were available, field measurements of water levels were made at key points in the treatment plant system during low and high sewage flows and during wet weather conditions. These field measurements extended from a low flow of 2.3 MGD to a high flow of 30.4 MGD. The resulting data confirmed the tightness of hydraulic conditions for the proposed facility, they showed that it was feasible to locate the facility as proposed in the preliminary plan. Subsequently, the final engineering plans for the facility were generated and approved.

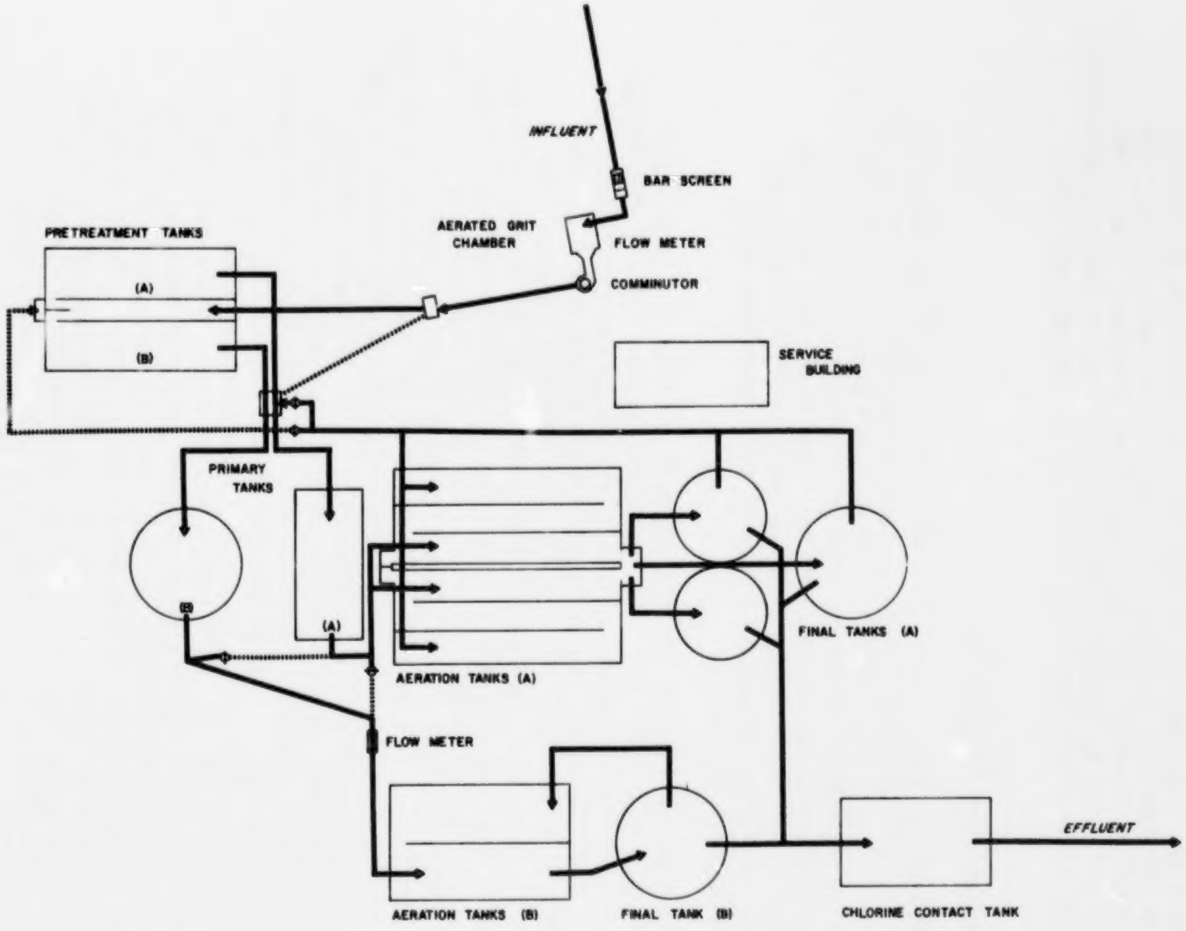
INFLUENT
BAR SCREEN
AERATED GRIT CHAMBER
FLOW METER
COMMINUTOR
PRETREATMENT TANKS
(A)
(B)
SERVICE BUILDING
PRIMARY TANKS
(B)
(A)
AERATION TANKS (A)
FINAL TANKS (A)
FLOW METER
AERATION TANKS (B)
FINAL TANK (B)
CHLORINE CONTACT TANK
EFFLUENT

Figure 1. Schematic Diagram of the Hagerstown Water Pollution Control Plant

The fundamental considerations that were made in the planning of the project facility were that: (1) the facility must fully meet the needs of the project program for such a structure, (2) the facility ought to be useable for post project pretreatment operations involving the entire plant including any likely plant expansions, (3) the wastewater flow into and out of the facility should be by gravity to obviate the need for pumping, (4) the loss of head through the facility must be minimal, (5) the Hagerstown treatment plant must be able to continue to operate while the facility is being constructed, and (6) the cost of the facility should be as low as reasonably possible.

2. Description of the Project Facility

The project pretreatment facility, which consists of two aeration tanks (i.e., pretreatment tanks) of compressed-diffused air design with their influent and effluent channels and a building for housing the facility equipment--blowers, electrical controls, wastewater monitoring and sampling units, chemical feed machines, etc.--was constructed as planned ahead of the primary settling tanks and downstream from the comminutor basin of the Hagerstown Water Pollution Control Plant.

A concrete manhole located 80 feet downstream from the comminutor basin was enlarged under the facility construction task of the project to receive a 42-inch concrete pipeline that also was built under the project to intercept the raw wastewater flow of the plant at the manhole and carry it some 100 feet to the aeration tanks of the pretreatment facility. Two stop gates were installed in the enlarged manhole in order that the raw sewage could be allowed to flow through either the 42-inch concrete influent line of the pretreatment facility or the original 42-inch line of the treatment plant in order to bypass the facility. The 42-inch influent line of the facility discharges into the head end of a grating-covered V-shaped channel formed in and running the full length of the coping wall that separates the two facility pretreatment tanks. An air diffusion system is installed in the coping wall channel itself to prevent deposition of wastewater solids in the channel. Toward the end of the coping wall channel, the channel is divided so as to split the wastewater flow into two separate streams. At the very end of the channel, these two flow streams are then directed downward through separate openings in the bottom of the divided channel and into vertical down channels that are formed in the corners of the pretreatment tanks. These vertical down channels extend below the line of air diffuser elements in the pretreatment tanks so that each of the two separate wastewater flow streams is introduced into its respective pretreatment tank at a point where rapid and vigorous mixing can occur.

Each pretreatment tank is 30'-0" wide x 95'-0" long with a 15'-0" maximum water depth for a total water capacity for both tanks of 6.30 x 10^5 gallons (8.40 x 10^4 ft^3). At the average design flow for the treatment plant (7.5 MGD) the water depth in the tanks is 14'-3" and total capacity of the tanks is 6.00 x 10^5 gallons (8.00 x 10^4 ft^3) for a detention time of 2.0 hours. The tanks as aeration basins are of the spiral flow design with swing type air diffusers (Chicago Pump "Swing Diffusers"). There are seven swing diffuser assemblies in each tank with 12'-10" air headers each equipped with 16 Chicago Pump "Shearfuser" air diffuser elements mounted on 9-inch centers and 7 evenly spaced Chicago Pump "Discfuser" diffusers mounted on piping that extend out from the headers to beneath the coping wall. The purpose of these discfusers is to prevent the formation during aeration of a dead volume (confined roll) under the appreciable overhang of the coping wall.

In the end wall of each pretreatment tank--the end wall at the head of the coping wall channel and opposite the end wall where the wastewater flow is introduced into the tank--a 48-inch wide rectangular opening is provided to connect the tank to a 48-inch wide rectangular channel that carries the tank effluent to the previously mentioned concrete division box of the treatment plant that distributes the wastewaters to the primary settling tanks. During all of the pretreatment studies except the last, pretreatment by the "select method" involving the operation of the entire treatment plant as a single system, this 48-inch wide effluent channel was divided by an asbestos-board divider wall into two channels to provide a separate channel for each pretreatment tank effluent. This division was carried up to and, as mentioned, through the concrete division box. In addition, because it was anticipated that low-flow velocities would exist in the 48-inch wide effluent channel, an air pipe line was installed in the channel in order that the effluent waters in either the channel as a whole or its divisions could be aerated to keep particulate solids in suspension.

In order to be able to bring waste activated sludge to the head ends of the pretreatment tanks and there to mix the sludge with the incoming raw wastewater as required by the project program plan, the 6-inch waste activated sludge line of the treatment plant that terminated in the concrete division box preceding the primary tanks was extended to the influent end of the pretreatment tanks where another concrete box was built to receive the extended line and to distribute the sludge to either or both of the coping wall influent channels of the pretreatment tanks. This sludge distribution to either or both influent channels was made controllable by means of adjustable discharge weirs in the concrete sludge distribution box, each weir leading to one channel in the coping wall. Pumping of waste activated sludge to the pretreatment tanks can be accomplished as required by one or both of two activated sludge pumps of the treatment plant. These pumps, which as stated earlier, have a capacity of 1900 gpm each when pumping sludge to the concrete distribution box ahead of the primary tanks, lose about 35% of their pumping capacity when pumping sludge to the sludge distribution box of the pretreatment tanks. This loss stems from the increase in the total dynamic head of the pumping system as a result of the extension of the sludge line. During the project, a single pump provided, as anticipated, all the pumping capacity necessary however to satisfy the sludge pumping requirements of the project program.

Housed in the mechanical building of the project facility are the following facility equipment, which were purchased and installed under the grant program:

(1) Two Ingersoll-Rand positive displacement blowers each capable of delivering to the pretreatment tanks 3500 cfm of air at 15 psig.

(2) Two mercury manometers reading 0 to 10 psig and mounted in the discharge piping of each blower to measure to the air pressure in the lines.

(3) Two Permutit Company Permatubes fitted with manometers and installed in the two air mains of the facility leading from the blowers to the pretreatment tanks. These are Venturi type devices for measuring the air flows to the pretreatment tanks.

(4) Three Chicago Pump Tru-Test Samplers for collecting and holding under refrigeration composite samples of the common influent (raw wastewaters) and the separate effluents of the two pretreatment tanks. These samplers are capable of sampling either proportionally to the raw wastewater flow (being paced by the plant flow meter located at the head end of the treatment system) or at a constant rate which is set by a timer-controller provided with each sampler. They are dip type samplers and each can take three to twenty 25-ml sample aliquots per hour and automatically composite them into a single sample and store the composite in a 2-gallon bottle kept in a refrigerated compartment in the unit.

(5) Three Megator L 100 positive displacement "Snore Pumps" for pumping the various wastewaters to the Tru-Test Samplers. These pumps are located next to the samplers in the mechanical building of the pretreatment facility and are driven by one horsepower, 1150 rpm electric motors through variable pitch pulley and belt drives to give a range of pumping rates.

(6) An electronic wastewater quality monitoring system for continuous automatic measurement and recording of the pH's, dissolved oxygen concentrations and oxidation-reduction potentials of the pretreatment tank influent and effluents. This system was manufactured by Automated Environmental System, Inc. During the project the

sensing probe assemblies of the system were mounted in the submersible, stainless-steel baskets that were placed just outside of the mechanical building of the project facility in the appropriate wastewater channels.

(7) An ammoniator-chlorinator for metering and feeding tank ammonia or chlorine in solution form into the pretreatment tanks. This device is a Wallace and Tiernan Modular Series V-800 Chlorinator with a capacity for feeding 2000 lbs of chlorine per day and, through slight modification, 950 lbs of ammonia per day. By means of the chemical feed-line-piping-and-valving arrangement of the project facility, the ammoniator-chlorinator can supply either ammonia or chlorine to either or both of the pretreatment tanks. The feed machine, for obvious safety reasons, is installed in a separate, well ventilated room in the mechanical building. On the open concrete pad of the building are located the manifolds and storage areas for the ammonia 150-lb and chlorine 2000-lb cylinders for the gas feed machine.

(8) Two chlorine scales, Force Flow Equipment Chlor-Scale Model 6D80, which are installed in the concrete pad of the mechanical building and are sized to hold and weigh two 1-ton chlorine cylinders each. The scales read from 0 to 8000 lbs.

(9) A dry chemical feeder for metering and feeding sodium nitrate and potassium permanganate to the pretreatment tanks. This is a Wallace and Tiernan, Inc., Screw-Type Volumetric Feeder, Series A-690, having a control feed range of 20 to 1 and a maximum feed rate for pelletized sodium nitrate of 1170 lbs/day and for "free-flowing" potassium permanganate of 312 lbs/day. The feeder meters and deposits powdered chemicals into a 35-gallon solution tank contained in its base where the dry chemicals with the aid of a mechanical stirrer are dissolved in tap water. From the solution tank, the dissolved chemicals can be fed by gravity flow to either or both of the pretreatment tanks. The machine is equipped with a 28-ft^3 hopper extension to provide a total hopper capacity of 6.0 ft^3. The additional hopper capacity provided by the extension allowed enough sodium nitrate to be stored in the machine that when the machine was used to feed sodium nitrate at the maximum rate, it refilled not quite once each shift. (Bulk density of sodium nitrate is approximately 75 lbs/ft^3)

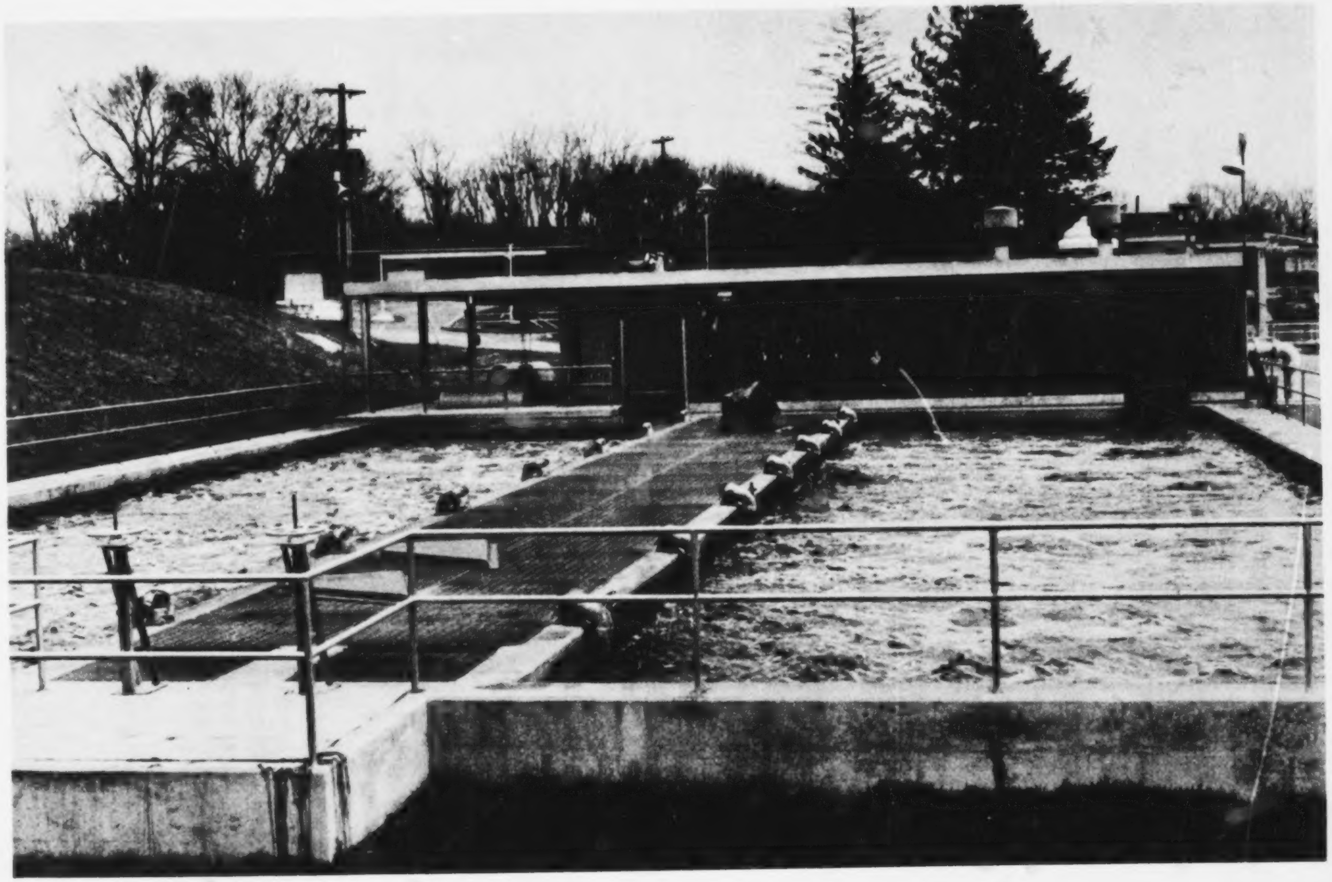

Figure 2. A View of the Pretreatment Facility from the Head End of the Pretreatment Tanks

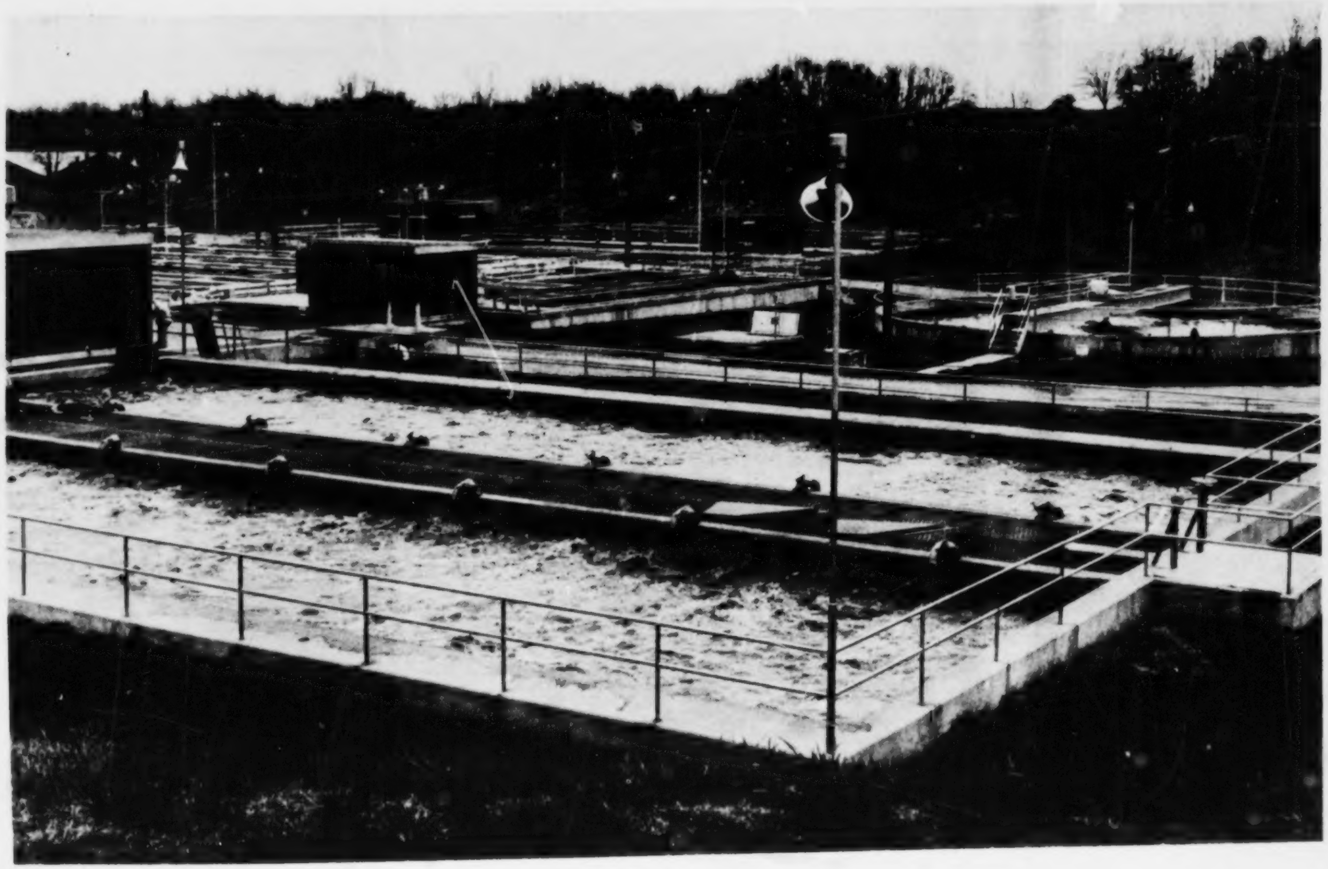

Figure 3. A View across the Pretreatment Tanks of the Project Facility, Showing the Primary Settling Tanks and Other Parts of the Hagerstown Water Pollution Control Plant in the Background

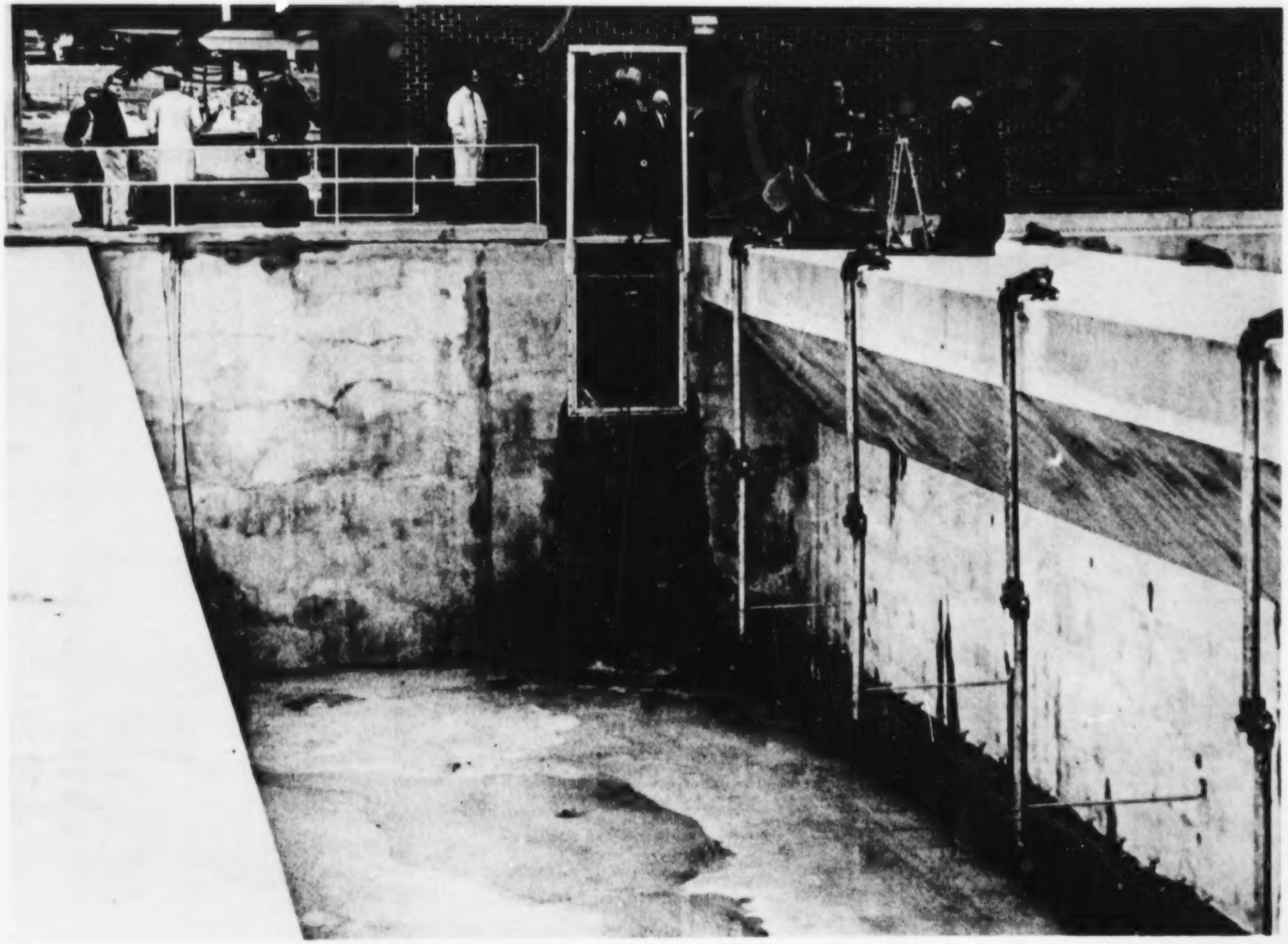

Figure 4. The Project Facility immediately prior to the Introduction of the Municipal Wastewaters into the Pretreatment Tanks

SECTION V

BASELINE STUDIES

A. Preliminary Wastewater Analyses

1. Establishment of Analytical Procedures

Shortly after the project was begun, an inventory of the equipment and chemicals in the laboratory of the Hagerstown sewage treatment plant was conducted and those laboratory items that the laboratory did not have but that would be needed for the project were purchased. As had been proposed, the purchases were made partly with project funds designated for this purpose and partly with "non-project funds" provided by the city. Once analytical systems were set up, laboratory personnel were trained by the professional chemists of the project team in carrying out those standard analytical tests that the laboratory personnel were not familiar with and that would be conducted routinely throughout the lifetime of the project.

All standard chemical analyses performed on wastewaters during the project except for the determination of the oxygen demand indicates (ODI's) and sulfite and hydrogen sulfide contents of wastewaters were conducted in accordance with the 12th Edition of Standard Methods for the Examination of Water and Wastewater, 1960, APHA, AWWA and WPCF. The ODI determinations were done following the Hach procedure patterned after the Department of Public Health of Illinois ODI test. The sulfite concentration measurements were done using the Hach SU-2 Sulfite Test Kit and the hydrogen sulfide concentration determinations were made by means of the Hach "Screening Test for Soluble Sulfides." These Hach procedures were adopted because of the rapidity and ease with which they could be performed by most of the personnel of the plant.

While laboratory personnel were being trained and for a short time thereafter, all the adopted standard analytical procedures were checked carefully and all the analytical instrumentation was meticulously checked to insure that all analytical measurements would yield reasonably accurate results for all the various analytical conditions that would be encountered in the different operational studies of the project. Moreover, several techniques for using gas chromatography to detect and to trace through the treatment plant various volatile organic components of the Hagerstown wastewaters were explored. Among the several candidate chromatographic techniques examined, the techniques or, more precisely, combination of techniques that were judged to be most suitable for the project and, therefore, adopted for project use were "freeze concentration" of the volatile wastewater organics for improved detection, injection and volatilization of the concentrated samples in the gas chromatograph, separation of the volatile organics on either a SE-30 or Porapak Q thermally programmed column, and detection of the separated components by means of a flame ionization detector. The gas chromatograph used was a Beckman CG-5.

2. Analysis of Wastewaters

While the project facility was being constructed, the mixed liquor suspended solids (MLSS) levels in the contact aeration tanks of the treatment plant were brought up to and maintained at 2500 ± 500 mg/l in order to have reasonable concentrations of biologically active solids in these tanks. Many analyses were then conducted on the wastewater flowing into, through and out of the plant in order to ascertain the nature of the raw wastewaters and the operational effectiveness of the various treatment plant sections as well as of the whole plant itself. These analyses, determined the baseline conditions of the project and are discussed in some detail below.

a. Sanitary Chemical Analyses

On each day of a seven-day period in July 1969, grab samples of the raw sewage and primary effluent were collected at 0100, 0200, 0300, 0400, 0500, 0600, 0800, 0900, 1100, 1500, 1700, 1900, 2100, 2300, and 2400 hours and grab samples of the final effluent of treatment plant section 3 (subsequently known as System B) were collected at 0300, 0600, 0900, 1200, 1600, 2000, and 2400 hours. Immediately after each sample was collected, its conductivity, dissolved oxygen concentration, and pH were measured. The samples were then acid preserved and, as soon as it was practical, their COD's and ODI's (oxygen demand indices) were determined with their colors being noted; in addition, the BOD_5's of those samples of (1) the raw sewage that were collected between 0100 and 0700 hours, (2) the primary effluent that were collected between 0200 and 0800 hours, and (3) the final effluent that were collected at 0300, 0600, 0900, and 2400 hours were measured. The BOD, COD, and ODI measurements gave exceptionally high values for the raw wastewater samples collected during the early morning hours of the week days. The COD and BOD values of the raw wastewater samples obtained during these times generally exceeded 1000 and 400 mg/l, respectively, with recorded highs of 1750 and 840 mg/l, respectively. During other times over the sampling period, BOD's values were less with the lowest values usually falling in the 30 to 40 mg/l range, while COD's values were also lower and dropped down into the 200 to 400 mg/l range. Thus, the raw wastewaters entering the treatment plant on week days were found to vary greatly in their pollutional strength, not only from day to day but from hour to hour. On the other hand, the BOD and COD values of the grab samples collected on the weekend that fell within the 7-day sampling period did not vary as markedly. Most of these BOD values were in the range of 30 to 120 mg/l; and most of the COD values, in the range of 130 to 400 mg/l. The BOD, COD, and ODI results obtained on the primary effluent grab samples were also higher for those samples collected during the week day morning hours than for those samples collected at other times; however, their peak values were never as high as the peak values obtained for the raw sewage samples and they lagged the raw sewage peak values in time by about two to three hours yet persisted for longer periods to show (as would be expected) that the slug loads that hit the plant during the morning hours were smoothed out somewhat as they passed through the primary tanks. A plot against collection times of ODI values obtained on samples of primary effluent that were grabbed hourly over seven consecutive days is shown in Figure 3. This plot dramatically illustrates the slugging of the aeration basins of the plant on week day mornings with a waste flow containing appreciable quantities of oxidizable materials. The BOD and COD results obtained on final effluent grab samples were in the ranges of less than 10 to 150 mg/l and 120 to 600 mg/l, respectively.

The chlorine demands of the raw sewage samples grabbed nearly once each hour over two separate 24-hour periods were determined for 30-, 45-, and 60- minute contact times. During the first of the 24-hour sample collection periods, the raw waste flow exhibited the early morning peak in ODI values, while during the second of the 24-hour periods the waste flow did not; however, the chlorine demands for both periods, even over the early morning hours, did not offer appreciably, running between 5 and 15 mg/l for 30 minute contact times. Chlorine demands at 45- and 60- minute contact times ran only slightly higher than those at 30-minute contact times.

Over another seven-day period, grab samples of the raw sewage, primary effluent, and Section No. 3 final effluent were collected hourly and composited daily, with sample preservation being effected during daily compositing period by refrigeration. The daily composites were then analyzed for their total phosphorous concentrations (soluble and soluble plus insoluble), oil and grease concentrations (by the Freon extraction procedure), COD's and BOD_5's (soluble and soluble plus insoluble), dissolved solids concentrations, suspended solids concentrations, specific conductances, chloride ion concentrations, pH's, and oxygen uptake rates. A similar set of daily composites spanning a third seven-day period were collected and analyzed for their ammonia nitrogen concentrations, organic nitrogen concentrations, nitrite nitrogen concentrations, COD's, sulfide concentrations, sulfate concentrations, total sulfur concentrations (sulfide, sulfite, hydrolyzable sulfonate, and sulfate sulfur as sulfate), specific conductances,

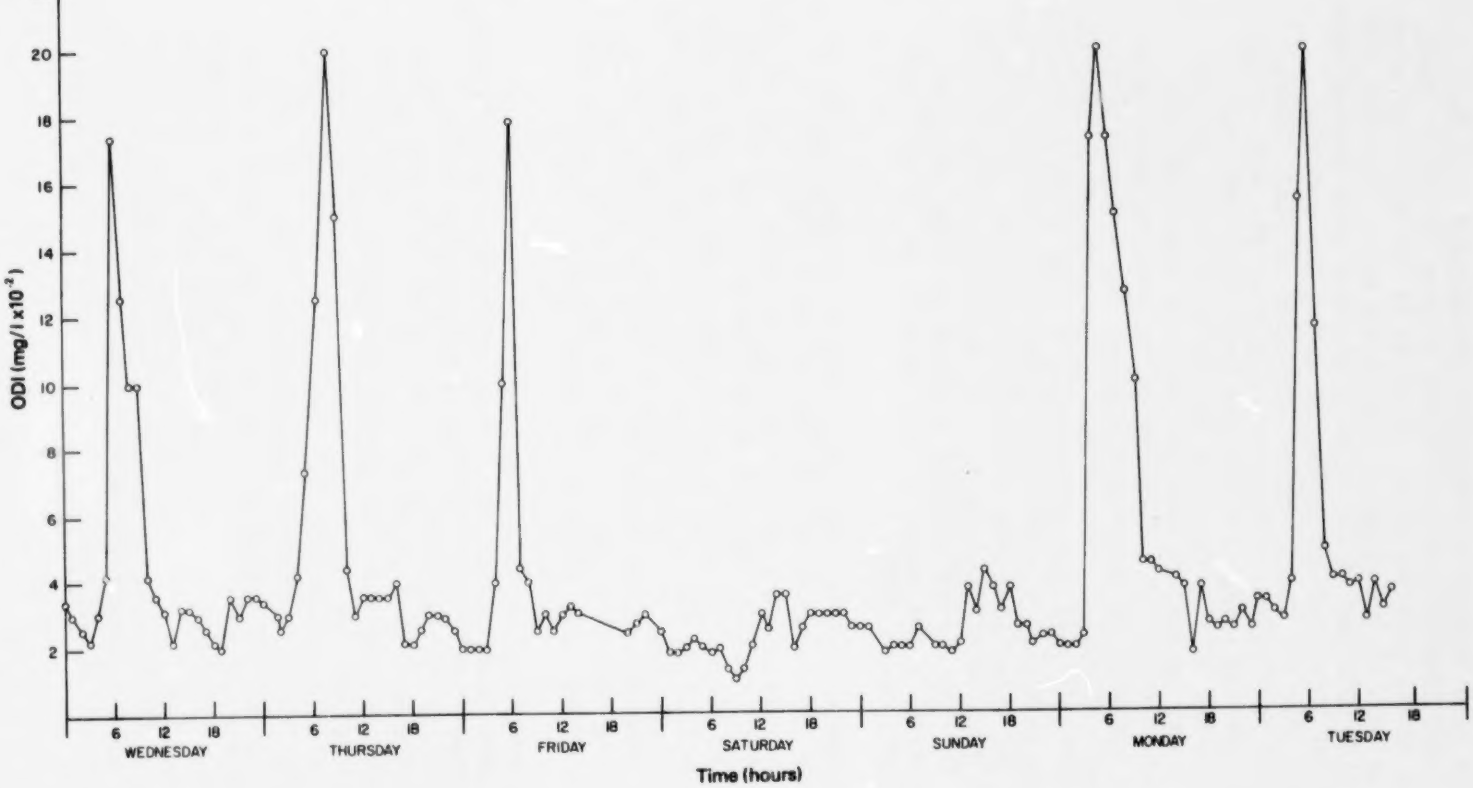

Figure 5. Oxygen Demand Indices (ODI's) of Grab Samples of Primary Effluent Collected over the period of October 18 to October 24, 1967

and pH's. The significant findings obtained from these analyses are summarized below:

(1) The BOD values of the composite samples of the raw sewage ranged between 200 and 300 mg/l and the BOD values of the composite samples of the final plant effluent (i.e., Section 3 effluent), from 45 to 150 mg/l with daily BOD removals averaging about 70%. The soluble BOD's of all the samples regardless of type--i.e., raw sewage, primary effluent or final effluent--were generally 70% of the total BOD's of the samples, although this percentage often varied quite widely among samples of even the same type.

(2) The concentrations of total phosphorus (expressed as orthophosphate) in the unfiltered samples fell in the range of 20 to 40 mg/l. The phosphorus concentrations in the filtered samples were not much less than the phosphorus concentrations in the corresponding unfiltered samples, thereby revealing that most of the phosphorus in the different wastewater samples was in solution.

(3) The chloride concentrations in the samples ranged between 48 and 75 mg/l and averaged 61 mg/l.

(4) Significant sulfide concentrations--0.1 to 3 mg/l--were present in nearly all samples.

(5) The total sulfur concentrations in the samples ranged between 80 to 120 mg/l as sulfate.

(6) The concentrations of ammonia nitrogen in the raw wastewater samples were about 20 mg/l while the concentrations of organic nitrogen were about only 5 mg/l. The relatively high ratio of ammonia N to organic, it is believed, is indicative of considerable decomposition of proteinaceous materials occurring in the raw wastewaters before these waters reach the treatment plant.

(7) Only rarely were there not detectable concentrations of nitrate or nitrite in any of the samples. Generally, all the samples including those of the raw sewage had nitrate and nitrite; but, the concentrations of these anions in terms of nitrate or nitrite nitrogen were never greater than 0.2 mg/l; and, in many of the samples, these concentrations were only at trace levels. In addition, the effluent samples consistently contained smaller concentrations of nitrate and nitrite than did the corresponding samples of raw sewage and primary effluent.

(8) The specific conductances of plant influent and primary and secondary effluent samples composited over a single 24-hour period varied little from one another; and, over the entire week of sampling, specific conductance values of daily composited samples fell in the rather narrow range of 180 to 390 μmhos/cm with 309 μmhos/μm being the typical value.

(9) Over the sampling period, the pH values of raw sewage samples averaged 7.2; the primary effluent samples, 7.2; and the final effluent samples, 7.4.

(10) The levels of suspended solids in both the raw sewage and the final plant effluent varied greatly from day to day. The suspended solids concentrations in 24-hour composite samples of raw sewage ran as low as 58 and as high as 986 mg/l and in 24-hour composite samples of the final effluent, from 22 to 196 mg/l. The volatile portion of the influent suspended solids also varied, ranging from 70 to 100%. Typically, the plant influent contained about 250 mg of suspended solids per liter while the plant effluent had about 95 mg per liter. The regular occurrence of high suspended solids concentrations in the final effluent was a major operational problem of the treatment plant and, except for the extremely frequent production of malodorous hydrogen sulfide gas by the treatment plant, was the most obvious deficiency in the performance of the plant.

In the baseline study, not only were sulfide concentrations of significant proportions found in grab and composite samples taken from various points throughout the treatment plant; but, by means of lead acetate impregnated filter papers suspended over the wastewaters at different points in the plant, hydrogen sulfide gas was found to evolve almost continuously from the wastewaters that were discharging over the effluent weirs of the primary and final settling tanks--as well as from the mixed liquors that were being aerated in the sludge reaeration and contact aeration tanks.

In extending the routine wastewater testing program of the treatment plant, sulfite tests on grab samples of the raw sewage were made regularly throughout the period of project baseline study. These tests were closely followed because of the high immediate oxygen demand that sulfites exert and because of the quite large sulfite concentrations that were reported to have been found entering the Hagerstown treatment plant prior to the initiation of the research project. The tests showed that during the baseline study sulfites were often present in the raw wastewaters for short periods of time, and that their concentrations generally ranged from 0 to 3 mg/l. Although sulfite levels as high as 7 and 10 mg/l were found, no concentrations of sulfite were detected that were as high (i.e., >25 mg/l) as many of those reported prior to the development of the project plan.

In addition to the dissolved oxygen analyses performed on the various wastewater samples, dissolved oxygen profiles of various plant sections were run with dissolved oxygen measurements being made *in situ* by means of a Weston-Stack dissolved oxygen meter. These measurements were made throughout the treatment plant every 8 hours over a 7-day period. Generally, extremely low dissolved oxygen levels were found to exist throughout the entire treatment system. Incoming wastewaters and the wastewaters in the primary tanks were found to have no dissolved oxygen, except rarely, then only in trace amounts. The wastewaters entering the aeration tanks often had slight amounts of dissolved oxygen as a result of having been discharged over the weirs of the primary tanks. Dissolved oxygen levels in the aeration tanks were usually in the order of tenths of a mg/l although they occasionally did reach 1 mg/l or more. The wastewaters in the final settling tanks usually contained no oxygen also but upon being discharged to the receiving stream did pick up some oxygen. As a rule, dissolved oxygen levels ran somewhat, though not appreciably, higher on the weekend than on the week days of the 7-day study period.

3. Oxygen Uptake Measurements

The rates at which the dissolved oxygen concentrations would be depleted in well aerated 24-hour composite samples of raw sewage, primary effluent, and final effluent was investigated. It was found that dissolved oxygen levels in well aerated (oxygen saturated) raw sewage and primary effluent samples that were collected on week days would drop from 7 mg/l to less than 0.5 mg/l in 25 to 35 minutes while in that same length of time the dissolved oxygen concentrations in well aerated final effluent samples that were also collected on week days would drop by only about 30%. It was also found that weekend samples of raw sewage, primary effluent, and final effluent consumed oxygen at appreciably lesser rates than their week day counterparts.

A number of mixed liquor samples were collected over the preliminary analysis task period of the project and the rates at which they took up oxygen were also measured, the measurements being made by means of Warburg Apparatus (Aminco, 18-station Model). Samples taken from the tail end of the sludge reaeration tank of Section No. 3 had oxygen uptake rates of 5 to 9 mg O_2/g MLSS/hour and samples taken from the head end of the contact aeration tank of the same section had oxygen uptake rates of between 10 and 20 mg O_2/g MLSS/hour. Besides these measurements, several 1:1 mixtures of sludge reaeration tank mixed liquor and composite raw sewage samples collected on week days were examined and they showed healthly oxygen uptake rates of around 20 mg O_2/g MLSS/hour. It is felt that these high uptake rates displayed by the mixtures strongly indicate that the wastewater used in the mixtures, which seemed typical of the raw sewage entering the treatment plant on week days during the project, contained no toxic and/or inhibitory substances.

The Warburg Apparatus was also used to check for the possible presence in the wastewater of toxic or inhibitory materials in another way: The 5-day BOD of a raw wastewater sample that was composited over a 24-hour week day period was determined by both the standard dilution method and the direct method, which requires the Warburg Apparatus. Both methods gave BOD_5 values for the sample that were in good agreement. Thus, dilution of the sample (which was 100:1 in the dilution method) had no major effect on its BOD_5 value. Consequently, it is reasonable to assume that in all likelihood toxic and inhibitory materials, if present in the raw sewage, were not present in sufficient amounts to affect biological activity.

4. Microscopic Examinations of Plant Biota

As a part of the preliminary analyses that were performed, microscopic examinations were made of the wastewaters from active parts of the Hagerstown treatment plant. These examinations revealed that the outstanding feature of the zoogleal floc mixes from the aeration tanks of the treatment plant was the universal presence of filamentous "sulfur bacteria" growing among relatively small and stringly zoogleal bacterial masses (see Figure 3). These filamentous sulfur bacteria were of the type commonly found in activated sludges receiving hydrogen sulfide, mercaptans, and other reduced sulfur compounds. The filamentous bacteria were readily distinguishable by their motility--they exhibited bending and creeping movements, much like the blue-green algae, Oscillatoria. They consisted of a series of nearly cylindrical cells, aligned in a common capsular sheath. Refractile masses of elemental sulfur appeared at intervals in the filaments. It is generally believed that these sulfur deposits represent the end product of the oxidation of hydrogen sulfide to sulfur and that the reaction is not carried further by the bacterial group.

Besides being found in the mixed liquors, the filamentous sulfur organisms were also observed in the raw sewage, and in the primary tank and final tank effluents. It is general experience that solids bearing filamentous bacteria settle poorly. Consequently, it was felt that if these sulfur organisms could be eliminated from the treatment system by destruction of hydrogen sulfide and other reduced sulfur compounds serving as their source of energy, a more

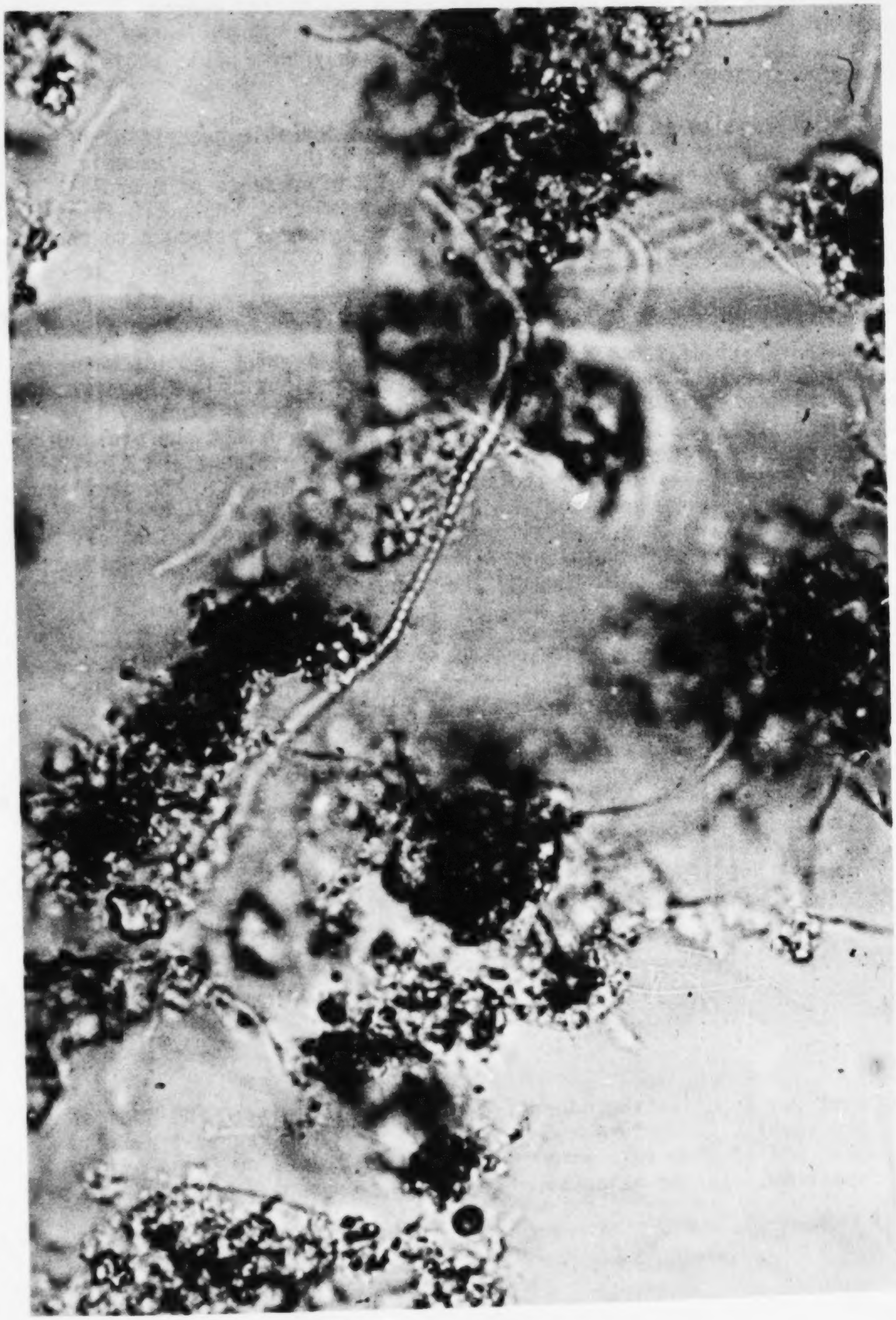

Figure 6. Photomicrograph of the Aeration Tank Mixed Liquors, Taken during the Baseline Study and Showing Filamentous Sulfur Bacteria Containing Globules of Sulfur and Growing among Masses of Zoogleal Bacteria

readily settleable floc would be generated and better management of the treatment process would be possible. It was hoped, of course, that the pretreatment schemes using oxidants would achieve this this destruction of reduced sulfur compounds.

It is interesting to note in view of the considerable quantities of hydrogen sulfide that were in the wastewaters that the microscopic examinations that were made did not reveal the presence of microorganisms of the type that produce hydrogen sulfide. However, it is believed that they were indeed in the plant, perhaps attached to the sidewalls of the various tanks.

5. Color Measurements

As another part of the baseline study, many wastewater samples were collected over a four-day period from three sections of the Hagerstown water treatment plant. The four-day period ran from a Thursday through a Sunday and the hourly and multi-hourly collections yielded representative grab sample of raw waste, primary effluent and final effluent, as well as 24-hour composites of these waters. The samples, over 90 in all, were analyzed to determine the color characteristics of wastewaters (which are usually intensely colored as a result of the dye wastes they contain) and how these characteristics changed as the wastewaters flowed through the plant.

The following observed trend and general conclusions were derived from the experimental data:

a) Typical color data in final form appeared as follows:

Type	Date	Time	% Luminance	Hue	% Purity
Raw	1/22	1100	84	greenish-yellow	5
Primary	1/22	1300	85	greenish-yellow	4
Final	1/22	1800	98	greenish-yellow	<1
Raw	1/23	1500	89	greenish-yellow	8
Primary	1/23	1700	94	yellow	2
Final	1/23	2100	97	yellow-green	1

b) Part (a) typifies the general trend in the samples. The hues of the samples seldomly changed significantly from raw to final and over 90% of them fell into the blue-green to yellow range of the spectrum. In the majority of cases, the degree of brightness was relatively high and increased from raw to final, while the corresponding values for color saturation were very low and decreased that same sequence.

c) Weekend grab samples were almost exclusively in the greenish-yellow range. Their percent purity and percent luminance indicated a somewhat better quality to the waste. This probably is attributable to lesser volumes of dye wastes discharged into the system at this time of the week.

d) The 24-hour composites displayed an overall lack of change from sample to sample. Only three of the eleven composites were not greenish-yellow, these three being green, blue-green, and yellow respectively. Here again, the percent purity was very low in all the samples.

6. Detection of Volatile Organics

As part of the investigation of treatment plant performance and wastewater characteristics, gas chromatography was employed to trace certain organic pollutants in the wastewaters through the various sections of the plant and to "fingerprint" the various industrial wastes entering the plant. Wastewater samples used in this work fell into three groups:

(1) Hourly grab samples taken from manholes near industries suspected of discharging high strength, extremely noxious, or toxic wastes into the city's sanitary sewerage system. The sampling points were chosen such that the wastes from any one particular industry would be isolated from those from any other industry. Some of these samples were collected from 0000 (midnight) to 0800 hours as part of an effort to locate the source or sources of the heavy load of high oxygen demanding materials that were entering the Hagerstown treatment plant during the early morning hours, week days.

(2) Twenty-four-hour composite samples of the plant influent collected each day of a seven-day period, which included week day and weekend wastewater representation.

(3) Twenty-four-hour composite samples of the plant influent, primary effluent, and final effluent collected at random times, weekly.

The chromatograph obtained on the grab samples of the wastewaters that were essentially industrial in nature (groups (1) samples) exhibited, as a whole, some 19 different peaks exclusive of the water and air peaks common to all chromatograms made on aqueous samples. It was evident from an analysis of the data that particular peaks or pollutants could be associated with particular industries.

Chromatograms of the group (2) samples, the 24-hour composites of the plant influent, distinctly showed at least six of the peaks found in the chromatograms of the group (1) samples. One especially predominate peak was traceable to wastes discharged by a textile dyeing and printing plant by correlation with the chromatographic information obtained on the group (1) samples. The other major peaks were attributable to the textile dyeing and printing plant also, and to a creamery. Other constituents appeared in the group (2) composites that were not detected in the group (1) samples; however, they were relatively minor. On the other hand, certain of the chromatographically detected components of the group (1) samples were not found in the group (2) samples, perhaps as a result of being reduced in concentration below G-C detection limits by dilution in the sewer system and by sample compositing. The group (2) samples collected on week days contained a greater number and larger amounts of chromatographable materials than did the group (2) samples collected on the weekend,as had been expected.

The chromatograms of the 24-hour composite samples of plant influent, primary effluent, and final effluent (group (3) samples) showed some of the same peaks as the chromatograms of the samples of groups (1) and (2). In following the chromatograms of the group (3) samples from plant influent to effluent, it was plainly evident that there were gradual decreases in the areas under some of the peaks, indicating decreases in the quantities of the wastewater components yielding the peaks, and certain influent chromatogram peaks were completely absent in the chromatograms of the final effluent samples. These decreases and disappearances may have been due to one or a combination of the following factors.

(1) the pollutants were actually degraded in the treatment plant,

(2) the pollutants were diluted in concentration as they passed through the plant,

(3) the pollutants, being volatile, were swept from the wastewater by aeration, and

(4) the pollutants were absorbed by suspended solids.

B. Survey of Industrial Plant

1. Introduction

Beginning shortly after the project was initiated, a limited survey of a select number of industrial plants located within the city of Hagerstown was conducted to discover the types and amounts of wastes these plants were discharging into the city's sanitary sewerage system. Since it was felt at the beginning of the project that the textile dyeing plants wastes and the wastes from the metal finishing and plating plants were imposing the greatest difficulties on the treatment plant, the textile dyeing and metal finishing and plating plants were the primary target of the survey effort.

Preparatory to the effort, a cursory literature study of modern textile dyeing and metal finishing and plating practices was carried out to familiarize the survey personnel with these practices. Also, a list of the various textile dyeing plants as well as other types of industrial plants utilizing the city's sewerage system was compiled, and waste-discharge-questionnaire-and-record booklets for issuance to the industries were prepared. From the compiled list of industries, key industries were selected to be surveyed. These industries then were sent a letter from the Mayor's office, explaining in general the project and in particular the planned survey and requesting the cooperation--in fact, the active participation--of these industries in the investigatory effort. These industries were screened further through actual in-plant visits by members of the project team; and, on the basis of plant size, nature of the wastes discharged, and the volumes of the discharges, nine of the candidate industries were finally chosen for the complete survey, the rest being dropped from further consideration.

Following the selection of the nine industries, top management pe[illegible] industries were given copies of the qu[illegible] with instruction for their completion and [illegible] these industries were begun. The purpose of the record booklets was to obtain in written form from each industry project pertinent information on plant practices and to establish in each industry a program of recording daily over the survey period the types and amounts of chemicals consumed and materials wasted during each day of operation. A set of the forms contained in the booklets may be found in the appendices of this report.

Over the survey period, which initially was allotted sixteen weeks of project time, a series of visits were paid by various members of the project team to each of the industries. During these visits, data recorded in the booklets were collected; plant operations were reviewed; supplemental information on plant waste disposal practices were secured; and, to promote the spirit of cooperation, questions about the project from plant personnel were encouraged and, when raised, openly answered. Without exception, each industry contacted responded to the survey undertaking with expressions of interest in the project and of willingness to participate in the survey. The favorable responses are attributed in part to the fine public relations efforts conducted by the city in regard to the project and the realization by the industries of the real necessity for the project, including the industrial survey.

2. Industries Surveyed and Survey Data Obtained

The industries surveyed and the survey data obtained are presented below:

(a) Mack Trucks, Inc. - 1999 Pennsylvania Avenue, Hagerstown, Md.

This plant of Mack Trucks, Inc., employ approximately 3500 persons, working in three shifts, seven days a week. It has about 1.02 million square feet of manufacturing area and produces the complete power train--engines and transmissions--for heavy duty trucks.

Prior to the project, this plant reportedly, was responsible for several sizeable oil dumps into the city's sewerage system that resulted in large quantities of oil reaching the municipal sewage treatment plant and severely impairing the performance of the treatment plant for periods of several days. However, just before the project was begun, the company installed and placed into operation two No. 150 Josam Oil Interceptors to prevent further such incidents.

The basic manufacturing operations of the Mack plant are cutting and heat treatment of metal engine parts. No metal pickling or plating operations are carried out. The oil necessary for the cutting operations is prepared and stored at a single location in the plant and pumped from that location through a piping system to the various metal cutting machines in the plant. Waste oils from the cutting machines are collected in four sumps situated strategically throughout the plant and then pumped from the sumps into a single waste oil storage tank. Ultimately, the waste oils are pumped from the storage tank into a tank truck for reclamation or disposal elsewhere.

Machined engine parts are washed free of excess oils in large industrial washers. There are 52 such washers in the plant and they use Mack 326 and 328 Alkaline Cleaners in the concentration of 1 to 3 oz of the alkaline base material to one gallon of water with approximately 180 to 360 lbs of the Mack 326 Cleaner and 700 to 1500 lbs of the Mack 328 Cleaner being consumed each week. Once a week, generally between midnight and 8:00 a.m., the cleaner solutions are discharged from the washers into the city's sanitary sewerage system. One third of the industrial washers are equipped with oil skimmers; the rest have drip drags which aid reportedly in oil removal.

The plant contains two recirculating cooling water systems, the waters of which are treated for corrosion control with chromate (25 to 50 mg/l), sulfuric acid and sodium polyacrylate. Approximately, 70 lbs of chromate (Dearborn 533), 2.6 lbs of 66° Bé sulfuric acid and 9 gallons of sodium polyacrylate are used weekly in the treatment of the waters. In addition, the cooling waters are also treated with sodium pentachlorophenate (Dearborn 711), a slimicide, of which about 21 lbs are used weekly. The "blow down" from these systems is set at approximately 2%, which amounts to a constant flow of about 15 gpm from one system and 10 gpm from the other. These blow-down discharges enter the city's sanitary sewerage system directly. However, any excess cooling waters from the boilers that supply hot water to the previously mentioned industrial washers are discharged into the storm drain system of the plant.

In the plant, certain machined metal parts undergo heat treatment for case hardening. Two different heat treatment processes are used. In one process parts undergo carburizing in a furnace. Some of these parts, immediately after removal from the carburizing furnace, are automatically oil quenched, then rinsed with water, which subsequently is wasted to the city's sewerage system. Other parts, after removal from the carburizing furnace, are held in a die press to hold their shapes until sufficiently cool, then subjected to an oil quench and finally a water quench. There are about one dozen water-quench-bath vessels in the plant for this process. These are 5' x 5' x 2.5' in size and, depending on the degree to which they are used, are generally dumped once a month into the sanitary sewerage system.

In the second heat treatment process, which involves liquid carburizing with the use of "Cyanobrik" (97% sodium cyanide briquettes), there are three baths; namely: a molten salt bath (Park Chemical Company "Nu-Sal", neutral salt, m.p. 1230°F), an electrolytic salt quench (Park Chemical Company "Thermo-Quench," m.p. 288°F), and a salt bath water quency (AJEM-33-S). The salt bath water quench is contained in only one vessel, whose dimensions are 2' x 2' x 1.5'. There is a continuous overflow from this vessel to the drain and the sanitary sewerage system; this overflow amounts to about 25 gallons per day. From 620 to 920 lbs of the AJEM-33-S material is used weekly to maintain the salt content of the quench bath.

Concerned about cyanide being introduced into the city's sewerage system as a result of the above heat treatment process, the project team sampled and tested the wastewater discharges of the Mack plant during the survey of the plant. These tests revealed no significant levels of cyanide in the discharges.

There is a research and development and engine testing area in the plant where engines are assembled, run, studied and disassembled. The floor drains in this area lead to the previously mentioned oil separators. Waste oils recovered by the separators are pumped into one of two waste oil storage tanks. One tank is for oils to be carted away; the other is for oils to be reclaimed. Waters from the separators are pumped into the sanitary sewerage system.

The plant has its own storm drain system, which surrounds the entire Mack facility; and, this system discharges into an earthen dam, which can store nearly 1.5 million gallons of stormwater. This drain system is not connected in any way to the city's sewerage system.

The plant wastes to the city's sewerage system an estimated 400,000 gallons of water daily.

(b) Pangborn Corporation - Pangborn Boulevard, Hagerstown, Md.

The Pangborn Corporation is a wholly-owned subsidiary of the Corborundum Company, Niagara Falls, New York. The Hagerstown facilities of the corporation employ more than 1200 people and are devoted to both engineering and manufacture of complete systems for cleaning, deburring, descaling, peening, etching and finishing the surfaces of metals and metal components and complete systems for industrial air pollution control. The manufacturing facilities consist of foundry, machine-shop, metal-working, wood-working, and assembly plants.

Essentially all manufacturing operations performed in the Hagerstown facilities of the Pangborn Corporation are "dry." Treatment of metals is done solely mechanically by means of the company's own devices--"Rotoblast" and air blast machines--consequently there are no chemical treatments, such as pickling, with highly acidic or alkaline liquid waste. In some metal cutting and drilling operations, oils and other lubricants are used; but, these substances are employed in only limited quantities; and, when they are spent, they are disposed of by being poured over the gravel bed of the railroad spur that serves the Pangborn complex. This method of disposal is practiced primarily for weed control and, reportedly, there are never enough spent lubricants for this purpose.

There are several air scrubbers for dust control located in various sections of the Pangborn facilities. The waters in these units are continuously recirculated (with evaporation losses continually replaced), and these waters are never discharged to the city's sewerage system. The sludges of fine particulate matter that collect in the scrubbers are continuously and automatically removed from the scrubbers by mechanical conveyor systems and deposited in drums, which, when full, are carted away from the Pangborn site for ultimate disposal of the sludges elsewhere.

Because all the manufacturing operations of the Pangborn facilities in Hagerstown are, in fact, dry, these facilities do not discharge any "industrial wastewaters" of any sort into the city's sewerage system.

(c) Potomac Dye and Print Corporation - 1000 Florida Avenue, Hagerstown, Maryland.

The Florida Avenue plant of the Potomac Dye and Print Corporation is one of two textile dyeing plants owned by this corporation in the City of Hagerstown. The second plant is located on Franklin Avenue in the city and its operations are reviewed subsequently. The Florida Avenue plant employs about 65 people and occupies approximately 51000 square feet of space.

Primarily, the plant roller prints synthetic fabrics with a water phase print system. The print vehicle is mineral spirits (Varsol) in water emulsion; and, all dye colors, emulsions, and resins used in the print colors are water soluble until they are dried and cured on the printed fabric in the printing process. Varsol comprises about 50% of any dye mixture.

In addition to several roller type printing machines, which incidentally use copper rollers that are etched with the print designs elsewhere, the plant contains four dye jigs, one dye box (2000-gallon capacity) and a large fabric washer with a stream dryer. The four dye jigs and the dye box are used for cloth "boil-off" and the washer-dryer for washing and drying back greige (cotton duck) and print cloth.

Typically, about 15500 yards of back greige and 37000 yards of fabric to be printed and washed and dried each day. Nearly 90% of the wastewaters discharged by the printing plant in the city's sewerage system are generated by the washer-dryer. In the washing process, only two chemicals are used--sodium pyrophosphate and sodium metasilicate. Approximately, 162 lbs and 49 lbs of these chemicals, respectively, are employed daily.

The entire plant consumes a total of about 112000 gallons of water a day, of which about 102000 gallons are ultimately discharged to the sewer and 10000 gallons are lost by evaporation in the cloth washing and drying operation.

Table 1. CHEMICALS AND DYESTUFFS CONSUMED BY THE FLORIDA AVENUE PLANT OF THE POTOMAC DYE AND PRINTING CORPORATION

Chemical	Purpose	Quantity Consumed	
		In 84 Days	Per Day
Chemical Division			
Press Cakes (all colors)	Pigments for Color Dispersions	8700 lbs	---
Monsanto Serox DJ (Alkylaryl Polyoxyethyle Ether)	Emulsifier	1870 lbs	---
Antifoam B	Antifoaming Agent	485 lbs	---
Pontamine White BT	Optical Bleach	54 lbs	---
Potassium Tripolyphosphate	Dispersing Agent	46 lbs	---
Titanium Titanox A-WD (Titanium Dioxide)	Titanium Pigment	2700 lbs	---
Methacel	Thickener	2500 lbs	---
China Clay	Filler	2410 lbs	---
Rohm & Haas Rhoplex HA-8 (Acrylic Emulsion)	Fabric Binder	3875 lbs	---

Table 1. continued

Chemical	Purpose	Quantity Consumed In 84 Days	Quantity Consumed Per Day
Mineral Spirits (Varsol)	Solvent	49000 lbs	
Dow Latex 881	Latex Binder	9000 lbs	
Polyacrylamide	Dispersing Agent	100 lbs	
Polyacrylate	Dispersing Agent	80 lbs	
Sodium Lauryl Sulfate	Wetting Agent	4015 lbs	
Monsanto Lytron 822	Emulsifier	610 lbs	
Aqua Ammonia	Cleanser	2955 lbs	
Butylated Melamine	Fabric Finish	4325 lbs	
Dipentene	Solvent	780 lbs	
Monoethanolamine	Dispersing Agent	95 lbs	
Thickener L	Thickener	2800 lbs	
RWA 325	Dispersing Agent	649 lbs	
Diethylene Glycol	Dye Solvent	435 lbs	

Table 1. continued

Chemical	Purpose	Quantity Consumed In 84 Days	Quantity Consumed Per Day
Print Division			
Rohm & Haas Paraplex G60	Print Softener	1090 lbs	13 lbs
Dow Antiform B	Antiforming Agent	1600 lbs	191 lbs
Ammonium Sulfate	Catalyst	500 lbs	6 lbs
Mineral Spirits (Varsol)	Solvent	2100 lbs	250 lbs
Dow Latex 881	Binder	20800 lbs	247 lbs
Natural Latex	Finishing	7300 lbs	87 lbs
Trimethylol Melamine	Fabric Treatment	920 lbs	11 lbs
Acetone	Solvent	21 lbs	1/4 lb
Back Greige and Print Cloth Washing			
Sodium Pyrophosphate	Cleanser	13600 lbs	162 lbs
Sodium Metasilicate	Cleanser	8300 lbs	99 lbs

The plant has nearly one floor drain for every 500 square feet of floor space. These drains lead to three below-the-floor sumps whose effluent lines eventually join into one line which empties into the city's sewerage system.

The plant has its own laboratory (referred to as the "Chemical Division" of the corporation) for preparing the color cakes and color dispersions used in the textile printing operations of the plant as well as plants of other companies. In general, it is not practical to give typical values for the quantities of chemicals and dyestuffs utilized in the preparation of the colors and in the textile printing operations of the plant on a daily basis since the printing operations vary considerably from day to day with respect to the types and amount of fabrics printed and colors used. However, the amounts of the various chemical and dyestuffs consumed in all plant operations over the 83 plant operating days that comprised the plant survey period were recorded and are tabulated on the next page; and, in those instances, where daily consumption values are meaningful these date are given also.

(d) Potomac Dye and Print Corporation - 367 East Franklin Street, Hagerstown, Maryland.

This is the second of the two plants of the Potomac Dye and Print Corporation in the City of Hagerstown; and, it has about 69 employees.

The plant dyes synthetic fabrics (materials of nylon, polyester, etc.), filaments or spun yarns and some cotton goods. In addition, it finishes all the cloth that is dyed in the plant and all the cloth that is printed in the Florida Avenue Plant.

The "dyeing operations" of the plant consist of the following cloth treatments:

(1) Washing with plain water
(2) Bleaching with hydrogen peroxide and "optical bleaches"
(3) Boil-off with detergents and alkalies
(4) Dyeing with either dispersed, acetate or direct colors

The application of finishes to cloth is done in baths which may contain water and water solutions of water repellents, resins, soaps, starch, urea, dullers and softeners. A list of the chemicals used during the survey period in both the dyeing and finishing processes is presented in Table 2 on the following page.

Table 2. CHEMICALS AND DYESTUFFS CONSUMED BY THE FRANKLIN STREET PLANT OF THE POTOMAC DYE AND PRINTING CORPORATION

Chemical	Purpose	Quantity Consumed In 84 Days	Quantity Consumed Per Day
Dyeing			
Disperse Acetate Dyes	Dyes	3862 lbs	46 lbs
Neozyme L (Enzyme)	Desizer	10400 lbs	124 lbs
Zinc Sulfoxalate	Stripper	650 lbs	8 lbs
Hydrogen Peroxide (35%)	Bleach	7950 lbs	93 lbs
Sodium Hypochlorite	Machine Cleaner, Bleach	900 gals	11 gals
Mineral Spirits (Emulsion Form)	Solvent	3370 gals	40 gals
Rock Salt (Sat'd. Brine Solution)	Dyeing	88100 lbs	1045 lbs
Wintergreen Oil (Methyl Salicylate	Carrier	115 lbs	1 lb
Trisodium Phosphate	Sequestrant	44000 lbs	524 lbs
Direct Viscose and Cotton Dyes	Dyes	3044 lbs	36 lbs

Table 2. continued

Chemical	Purpose	Quantity Consumed In 84 Days	Quantity Consumed Per Day
Ammonia Solution	Cleanser	2333 lbs	28 lbs
Sodium Silicate	Detergent	8522 lbs	101 lbs
Muriatic Acid (Hydrochloric Acid)	Acid	224 lbs	3 lbs
Acetic Acid	Acid	6060 lbs	72 lbs
Sodium Nitrite	Dyeing Assistant	1431 lbs	17 lbs
Proctor & Gamble Olate Flakes	Detergent	2225 lbs	27 lbs
Sodium Bisulfite	Reducing Agent (Anticlor)	50 lbs	1/2 lb
Soda Ash (Sodium Carbonate)	Detergent		
Monsanto Sterox CD (Polyoxyethylene Ether)	Detergent	2494 lbs	30 lbs
Dow Versene 100 (EDTA)	Sequestrant	900 lbs	11 lbs
Finishing			
Secondary Butyl Alcohol	Solvent	2313 lbs	28 lbs
Dow Antifoam B	Antifoaming Agent	1080 lbs	12 lbs

Table 2. continued

Chemical	Purpose	Quantity Consumed In 84 Days	 Per Day
Amcur Arquad 2HT-75 (Quarternary Ammonium Compound)	Softener	2779 lbs	33 lbs
American Cyanamide Dicyandiamide	Buffer for Resins	2650 lbs	32 lbs
American Cyanamide Resin M3 (Trimethyol Melamine)	Fabric Treatment	21450 lbs	255 lbs
American Cyanamide Resin 23 Spec.	Fabric Treatment	6585 lbs	78 lbs
Dow Dowicide A (Sodium o-Phenylphenate Tetrahydrate)	Preservative	50 lbs	1/2 lb
Magnesium Chloride	Catalyst	2350 lbs	28 lbs
White Bentonite (Natural Aluminum Silicate)	Duller	550 lbs	6 lbs
Gum Tragacanth (Natural Gum)	Finishing	318 lbs	4 lbs
Monsanto Mersize (Resin Soup)	Detergent	4000 lbs	48 lbs
Monsanto Syton DS (Colloidal Silica)	Antislip Finish	2200 lbs	262 lbs
Monsanto Sterox DJ (Alkylaryl Polyoxyethylene Ether)	Detergent	5644 lbs	67 lbs

Table 2. continued

Chemical	Purpose	Quantity Consumed In 84 Days	Quantity Consumed Per Day
Sodium Formate	Gas Fading Inhibitor	16500 lbs	196 lbs
Titanium Pigment Corp. Titanox A-WD (Titanium Dioxide)	External Delustrant	200 lbs	2 lbs
Urea	Weighter (with starch)	11400 lbs	136 lbs
Aluminum Acetate	Water Repellent	350 lbs	4 lbs
Glacial Acetic Acid	Water Repellent Preparative	330 lbs	4 lbs
Dupont Zelon S (Aqeous Dispersion of Polymer Wax)	Water Repellent	1117 lbs	13 lbs
National Starch Korfilm 50 (Starch)	Finishing	30400 lbs	361 lbs
American Cyanamid Aerotex Reactant 1 (Cellulose Reactant)	Wrinkle Recovery	13387 lbs	159 lbs
American Cyanamid Cyanolube Softener 40 (Polyethylene Emulsion)	Softener (Resin Finishes)	8000 lbs	95 lbs
American Cyanamid Cyanolube Softener SB100	Softener	2133 lbs	25 lbs

During a typical operating day, the plant dyes some 78500 yards of cloth and finishes some 109300 yards, utilizing in these processes about 130000 gallons of water. Of this volume of water consumed daily, about 41000 gallons are lost through evaporation and 91000 gallons are discharged into the city's sanitary sewerage system.

Before the discharged process wastewaters reach the sewer, however, they are funneled by the floor drain system of the plant into an 8-foot diameter by 15-foot deep holding tank. Reportedly, this tank is cleaned out every two months by a private disposal company.

(e) Associated Ribbon Works - 655 N. Prospect St., Hagerstown, Md.

The Associated Ribbon Works employs 33 persons and engages in the dyeing of ribbon. The ribbon materials processed by the plant are generally made of rayon, acetate, cotton-acetate, rayon-acetate and nylon and vary in widths from 1/4 inch to 5 inches.

Ribbon is handled in skein form. Before being actually dyed, it is cleaned (scoured) with hot alkalies and detergents, bleached in sodium hypochlorite solution, water rinsed and then treated with an antichlor. Some of the ribbon so processed is not subsequently dyed but is retained as white stock. Most of the ribbon, however, is dyed, and aniline type dyestuffs are used in the dyeing process. These dyes are applied to the ribbon fabric in boiling liquors that contain in addition to the dyes used during the period this industry was surveyed can be found in the table given on the following page. The plant does not do any ribbon finishing; instead, it sends the ribbon it has processed to the Maryland Ribbon Company plant on Willow Circle in Hagerstown for this treatment.

The day-to-day dyeing operations are not carried out in accordance with any regular schedule. Consequently, water useage varies between 55000 to 102000 gallons per work day. Moreover, all processing is done on a batch basis with spent scouring, bleaching, rinsing and dyeing baths never being regenerated; each bath is dumped immediately after each bath operation is completed. The spent liquors are discharged into floor trenches which convey the waste to a single drain line which discharges directly into the city's sewerage system.

Table 3. CHEMICALS AND DYES USED BY THE ASSOCIATED RIBBON WORKS

Chemical	Purpose	Average Daily Useage
Dyes	Dyeing	32 lbs
GAF Igepon T-5 (Sodium N-methyl-N-oleoyl taurate)	Leveling & Dispersing Agent	13 lbs
Sodium Pyrophosphate	Water Conditioner	17 lbs
Laurel Vidol Flake Soap (Low Titre Soap)	Detergent & Dispersing Agent	10 lbs
Laurel Laurel 65-3	Leveling Agent	13 lbs
Rumford Quadrofos (Sodium Tetraphosphate)	Water Conditioner	7 lbs
Glaubers Salt (Sodium Sulfate Decahydrate)	Exhausting Dyes onto Fabric	71 lbs
Soda Ash (Sodium Carbonate)	Cleaning & Dyeing	100 lbs
Sodium Bicarbonate	Dyeing Catalyst	4 lbs
Sodium Hypochlorite Solution	Cotton Bleach	20 lbs
Sulfuric Acid, 66° Be	Neutralization in Bleaching	8 lbs
Sodium Bisulfite	Reducing Agent (Antichlor)	6 lbs
Althouse Resamide Extra	Stain Prevention	0.5 lbs
Althouse Resogen FWL	Making Dyes Washable	0.5 lbs
Brine (Sat'd. Sodium Chloride Solution)	Direct Dyeing	57 gals
Acetic Acid	Acidifying	7 lbs

Table 3. continued

Chemical	Purpose	Average Daily Useage
Ciba Albatex BD (Sodium m-Nitrobenzone sulfonate)	Leveling Agent	4 lbs
TNA-5 Salt (Sodium Chloride)	Direct Dyeing	277 lbs
Althouse Metachloron	Color Migration Preventative	4 lbs
Formaldehyde	Making Dyes Washable	3 lbs
Caustic Soda (Sodium Hydroxide)	Cleaning Agent	11 lbs
GAF Dizopon SS837	Leveling Agent	0.3 lbs
Royce Vatrolite (Sodium Hydrosulfite)	Stripping Agent	7 lbs
Ammonia Sulfate	Acidifying in Dyeing	2 lbs
Tanatex Gas Inhibitor A (Neutral Alkylamine Derivative)	Atmospheric Fading Preventative	1 lb
Muriatic Acid, 20% Hydrochloric Acid)	Acidifying (Resin Removal)	8 lbs
Sandoz Revatol S (Sodium m-Nitrobenzene sulfonate)	Leveling Agent	1 lb
Royce Parolite (Zinc Formaldehyde Sulfoxalate)	Stripping Agent	0.5 lb
Olin Mathieson Textone (Sodium Chlorite)	Stripping Agent (Nylon)	0.1 lb

Table 3. continued

Chemical	Purpose	Average Daily Useage
Tanatex X-Tan Special C (Sodium Alkyl Oleate Sulfonate)	Corrosion Control (w/Terbine)	0.3 lb
Oxalic Acid	Rust Stain Removal	0.1 lb
Aqueous Ammonia, 29%	Acid Neutralization	0.2 lb
Sandoz Sandofix WE-51 (Cationic Resinous Compound)	Fixation of Colors	3 lbs

(f) Maryland Ribbon Company - 857 Willow Circle, Hagerstown, Md.

The Hagerstown plant of the Maryland Ribbon Company both finishes and packages ribbon and related narrow fabrics for marketing. Most of the 225 employees of the plant are engaged in packaging and shipping of ribbon--operations, which do not involve the use of any chemicals of any nature that may ultimately end up in the sanitary sewerage system of the city. About only seven plant employees are assigned to the ribbon finishing operations of the plant.

For the main part, ribbon finishing is done automatically by machines which pass the ribbon to be treated through small, narrow baths of water solutions and suspensions of finishing materials, namely, resins and water soluble starches. Most of these solutions and suspensions are absorbed by the fabrics in the treatment process and as the ribbons are dried by the steam dryer associated with the finishing machines the water of the solutions and suspensions is of course driven off by evaporation. As a result, the plant generates a minimal amount of liquid waste from its finishing operations. In fact, it discharges about only 45 gallons of process water per day while it consumes about 250 gallons of process water daily. The waste finishing liquors are discharged to the city sewer only between machine runs (and at the end of each work day since the contents of the finishing baths are not held over from one working day to the next) when the finishing baths are flushed free of their contents.

The plant uses only a limited number of substances in its ribbon finishing operations and these substances are summarized in the table on the following page.

(g) Victor Hosiery - 775 Frederick Street, Hagerstown, Md.

Victor Hosiery, which has about 30 employees, both manufactures (weaves) and dyes nylon stockings and panty hose for women.

Only the dyeing and associated scouring and stripping processes of the plant yield any industrial wastewaters. The volume of wastewater resulting from these operations amounts to approximately 1024 gallons each working day. These waste enter directly into the city's sewerage system.

The plant dyes nearly 10000 dozen pieces of hosiery weekly. Dyeing as well as scouring and stripping is done in batches (500 dozen pieces per bath) and carried out in seven barrel type dyeing machines. Upon completion of any of these operations, the liquid contents of the dyeing machines being used are dumped. Generally, the actual scouring and stripping operations are followed immediately by one or two plain water rinses that are effected in the dyeing machines. The spent rinse waters are of course released to the city's sewer, also. During the 20-week period over which the Victor Hosiery plant was surveyed, stripping, which involves the use of sodium hydrosulfite, was generally performed only once or twice a week although there were some weeks in which stripping was not done at all or as frequently as four times (days) a week.

The plant uses a variety of chemicals and dyestuffs in its dyeing operations. These materials and the amounts of them that are consumed during a typical work day are given in the table on the next page. As noted in the table, a few of these listed materials are used only very infrequently.

(h) W. H. Reisner Manufacturing Company, Inc. - 240 N. Prospect Street, Hagerstown, Maryland.

This industry employs 73 people and produces pipe organ supplies, screw machine products and, for the U. S. Navy, radar plotting boards. It is housed in two separate buildings, which are located adjacent to each other and are considered by the company as two separate and distinct manufacturing plants.

The manufacturing operations of the industry are essentially metal working and metal treatment although the industry does do some woodworking, cabinet making and electrical wiring in addition. The primary metal operations of the industry are: die casting (zinc), press forming and blanking, heliarc welding of aluminum sheets and extrusions, chemical cleaning of metal parts, chemical preparation of metal surfaces for painting and plating and the painting and plating of metal products.

Chemical cleaning and chemical preparation for painting and plating of metal surfaces and the actual plating of metals are essentially the only industrial processes of the Reisner Manufacturing Company that generate wastes that are eventually discharged to the city's sewerage system. The industry consumes on the average about 10000 gallons of city water per day. Of this amount, approximately 750 gallons are used for sanitary purposes and 9250 gallons for industrial purposes. Almost all the water employed for industrial reasons is used for cooling various plant equipment; namely, two compressors, a die caster, a spot welder, a heliarc welder and a vapor degreaser. The cooling waters from the heliarc welder and vapor degreaser are passed through the hot water rinse tanks of the metal cleaning and plating operations. The overflow from the rinse tanks and the cooling waters from the plant

Table 4. CHEMICAL USED BY VICTOR HOSIERY COMPANY

Chemical	Purpose	Average Daily Useage
Geigy Cycoluce Yellow G	Dye	0.5 lb
Textile Chemical Cellutate Brilliant Blue B Sepia	Dye	0.5 lb
Geigy Setacyl Scarlet RNA Sepia	Dye	0.4 lb
Osco Chemical Auto Dye 63-50	Dye	35 lbs
GAF Celliton Orange GRA	Dye	3 grams
Geigy Erio Black J	Dye	0.2 lb
Geigy Tinopal WHN Liquid	Dye	0.1 lb
Textile Chemical Assoc. Fascadye 201 LF	Detergent (Scouring)	7 lbs
HyChem Resilube T-5	Finishing	1 lb
HyChem Migratex 39	Scouring	1 lb
Caustic Soda (Sodium Hydroxide)	Scouring	1 lb
Royce Sodium Hydrosulfite	Stripping	1 lb
Asco Chemical Oscotol 300	Water Treatment	2 lbs
Scholler Brothers Allo-Scour	Scouring	(See Note 1 below)
Laurel Products Vidol Soap Flakes	Detergent	(See Note 2 below)

Table 4. continued

Chemical	Purpose	Average Daily Useage
Soda Ash (Sodium Carbonate)	Scouring	0.2 lb
Geigy Alrosol CS (Fatty Acid Amine Condensate)	Detergent (Scouring)	0.1 lb

Notes:
1. Allo-Scour was used on only two days during the 20-week period over which chemical useage data on Victor Hosiery was collected and on each of these days the amount of material used was only 0.5 lb.
2. Vidol Soap Flakes was used on only three days during the 20-week survey period and on these three days the useage was only 1, 3 and 2 lbs, respectively.
3. A total of only 15 grams of Celliton Fast Pink FF 3BA were used during the 20 week survey period.

TABLE 5. DAILY CHEMICAL USEAGE OF THE MARYLAND RIBBON COMPANY

Chemical	Purpose	Amount Used Daily
Rohn & Haas Rhonite R-1 (Urea-Formaldehyde Resin)	Wetfastness & Shrinkage Control	106 lbs
Rohm & Haas Catalyst H-7 (Zinc Complex)	U-F Resin Catalyst	15 lbs
Althouse Polyanthrene KS	Wetfastness	14 lbs
A. E. Staley Solvitose H (Potato Starch-Ether)	Finish	56 lbs
Colloids Vicol 175 Vinyl Acetate Copolymer)	Finish	47 lbs

equipment other than the heliarc welder and vapor degreaser are wasted into the city's storm sewer system. However, only the air compressors operate continuously and, consequently, use and discharge water to the sewer. The welding, cleaning and plating operations are performed on a rather irregular schedule depending, of course, on the work load of the industry and may on some days be carried out not at all or for only a few hours.

Because of the irregularity of the metal cleaning and plating operations and the rather small amounts in which many of the chemicals employed in these operations are used, it was difficult to obtain meaningful typical chemical useage data on the industry even over the rather extended period of time of the survey effort. Fortunately, however, the company maintains from year to year fairly accurate records of its chemical purchases, and it made these records available to the survey team. The table on the following page presents data on the average amounts of chemicals used by the company over a year, data based on both the company records and direct findings of the survey.

3. An Extension of the Survey

(a) The Search for a Waste Source

None of the data gathered in the survey of the industrial plants of the City of Hagerstown provided any explanation for the occurrence of the high chemical and biochemical oxygen demands that, as revealed during the baseline studies of the project, were regularly exhibited by the wastewater flows reaching the Hagerstown wastewater treatment plant during the early morning hours on week days. Since it was felt by the members of the project team that the wastes that created these high demands were probably being discharged in the city's sewerage system by a single industrial plant and since the wastes exerted such a significant impact on the city's treatment plant and, of course, on the operational studies of the project, which, at the close of the scheduled portion of the survey effort, were well underway, it was decided that the source of these wastes ought to be found to disclose the exact nature of the wastes.

The plan exercised to locate the waste source was simply to track the slug discharge back up the sewer line from the plant until the point of discharge was found. Over several workdays, grab samples of the wastewaters flowing in various sewer mains serving the major sections of the city were collected hourly over the time period of 11:00 p.m. to 7:00 a.m. and the oxygen

Table 6. CHEMICAL AND MATERIALS USED BY THE W. H. REISNER MANUFACTURING COMPANY

Chemical	Purpose	Amount Used Yearly
Plant No. 1 ("Main Plant")		
Wyandotte Nu-Vat (Hot aqueous solution)	Metal Cleaning	(See Note 1)
Wyandotte F-S	Metal Electrocleaning	(See Note 2)
Nickel Sulfate	Nickel Electroplating (Barrell plating)	500 lbs
Nickel Chloride	Nickel Electroplating (Barrell plating)	100 lbs
Boric Acid	Nickel Electroplating (Barrell plating)	50 lbs
Zinc Cyanide	Zinc Electroplating (Barrell plating)	250-300 lbs
Sodium Cyanide	Zinc Electroplating (Barrell plating)	200-250 lbs
Sodium Hydroxide	Zinc Electroplating (Barrell plating)	150 lbs
Muriate Acid, 20° Bé	Pre-plating Etching	80 gals
Nitric Acid, 42° Bé	Pre-plating Etching	14 gals
Sulfuric Acid, 66° Bé	Pre-plating Etching	14 gals
Perchloroethylene (tetrachloroethylene)	Solvent (Vapor Degreaser)	330 gals (See Note 3)
Plant No. 2		
Oakite #160 (Hot aqueous solution)	Metal Cleaning	900 lbs (See Note 4)

Table 6. continued

Chemical	Purpose	Amount Used Yearly
Oakite #34	Deoxidizer	500 lbs
Allied Iridite #14.2	Painting Pretreatment	20 lbs

Notes:

1. Nu-Vat, a product of Wyandotte Chemical Corporation, is a synthetic detergent preparation, which, reportedly contains no cyanides, chromates or cresoles. It is used in hot aqueous solution, 2 to 4 ounces in one gallon of water. When metal cleaning is being carried out, the maximum amount of Nu-Vat solution that is discharged to the sanitary sewer per day is about 50 gallons. All discharges are batch.

2. F-S, also a product of Wyandotte Chemical Corporation, is a phosphate cleaner which is mixed with water in the proportions of 6 to 10 ounces of F-S per gallon of water.

3. Every two months, about 4 gallons of perchloroethylene, which is used as the solvent in the company's metal vapor degreaser, are discharged to the sanitary sewerage system.

4. The tanks containing the Oakite #160 solutions are dumped only once or twice a year, depending on their use, with the liquid being discharged to the sanitary sewer and tank sludges being hauled away.

demand indices (ODI's) of the samples determined. In addition, in order to confirm that the waste slug was indeed entering the treatment plant on the mornings of the sewer main sampling, grab samples of the plant influent were also collected hourly over the early morning hours and their ODI's subsequently measured.

Prior to the initiation of sample collection in the source search effort, time-of-flow measurements were made in the sewer lines to establish the appropriate starting time of each sewerline samples were not collected to late, i.e., after the slug of waste had passed the selected sampling points. These measurements also gave some feel for the residence time of wastewaters in the different sewerline sections examined. They were made by injecting dye (rhodamine B) into the sewage flow at various points at the extremes of the sewerage system and then timing how long it took for the dye to reach the treatment plant. The longest flow time measured--1 hour and 55 minutes--occurred in the extensive "north line" which serves the northern section of the city, with the dye injection being made at the extreme end of the line, at the Mack Truck plant. Flow times from the extremes of other sewer lines--east, south and west--ran about an hour or less. Therefore, it was concluded that an 11:00 p.m. starting time for each sampling period was sufficiently early to catch the slug no matter where in the system samples were collected.

By this sampling technique, it was discovered that the waste with the high chemical oxygen demand was coming to the treatment plant through the west line. Subsequently, intensive sampling of this line was conducted over a period of a couple weeks, the sampling crew moving up the line from one key manhole to the next. As a result, the source of the potent wastes was isolated and found to be a cheese plant belonging to the Breakstone Sugar Creek Foods Division of the Kraftco Corporation.

(b) Breakstone Sugar Creek Foods Division, Kraftco Corporation - 500 McDowell Avenue, Hagerstown, Maryland.

Immediately after the Breakstone Foods plant was discovered to be the source of the slug waste discharges of concern, it was included in industrial survey effort of the project. As had been done with the other industries surveyed, in-plant inspections were made of the industry by members of the project survey team. Key personnel of the Breakstone Sugar Creek Food Division upon learning of the inclusion of cheese plants in the survey cooperated fully with the survey team and supplied the team with all requested plant operating data.

The plant, which employs 26 persons, produces cottage cheese, sour cream and sour dressing. In the plant, whole milk is separated into cream and skim milk, which are then pasteurized. The pasteurized skim milk is put in vats, a culture of lactic acid bacteria "starter" is added to it, and the milk is incubated until the curd is set (i.e., until a firm coagulum is formed). The curd is then cut into small pieces and heated until the desired amount of whey has been expelled from it and it develops the texture sought. The whey is then drained off and wasted and the curd washed. The washed curd is subsequently pumped to blenders, which blend cream dressing into the curd. From the blenders, the finished creamed cottage cheese is packaged into containers of various sizes, placed into shipping cartons and moved to refrigerated storage in preparation for shipping.

The pasteurized cream is made into either sour cream, sour dressing or sweet cream dressing. These products are packaged separately or mixed with the cottage cheese curd.

At the end of a day's operation, or earlier when convenient or necessary, all of the plant process equipment is washed with an alkaline cleaner and sanitized with a chlorine solution; and, as needed, mineral deposits in the equipment are dissolved away by the use of diluted phosphoric acid solution. The various chemicals employed in these operations and added to the boiler waters (the blow-down fraction of which enters the city's sewerage system) of the process heaters and the amounts of them consumed per working day are given in the table on the next page.

Plant operations are shut down on Fridays and started up again on Sundays. Cottage cheese whey is discharged to the city's sewage system every week day, sometime between midnight and 4:00 a.m. The volume of whey discharged each time is about 7700 to 8000 gallons. The spent wash waters from the curd washing operations, which immediately follows the dumping of the whey, are also discharged to the city's sewerage system, the discharge time occurring between 1:30 and 6:30 a.m. and the discharge volume being about 23,000 to 26,000 gallons. On Sundays, Mondays, Tuesdays, Wednesdays and Thursdays the total volume of process water--which includes the cottage cheese wash water, cooling and heating water, and equipment and plant washdown water--that is used and discharged to the sewer daily ranges from 120,000 to 140,000 gallons. On Fridays, process water consumption drops to around 80,000 gallons; on Saturdays, to about 10,000 gallons.

Table 7. CHEMICALS AND OTHER SUBSTANCES USED IN PROCESSES OF THE BREAKSTONE FOODS PLANT

Chemical	Purpose	Amount Used Daily
Sodium Hypochlorite Solution (6%)	Sanitizing	30 gals
Phosphoric Acid (75%)	Millstone Remover	55 lbs
Liquid Detergent	Cleaning	3 qts
Manual Cleaner	Cleaning	50 lbs
All-Metal Recirculation Cleaner	Cleaning	30 lbs
Hi-Alkaline Cleaner	Boiler Additive	33 lbs
Garrett Calahan 153	Boiler Additive	7 lbs
Garrett Calahan 101-CF	Boiler Additive	17 lbs
Garrett Adjunct SS-CAT (Sodium Sulfite)	Boiler Additive	2 lbs

(c) Pollutional Significance of Whey

In the dairy industry, the disposal of cheese whey--especially whey resulting from the manufacture of cottage and cream cheese--has always been a problem. Currently, about 22 billion pounds of whey are produced each year in the United States and about one half of this amount goes to waste. Therefore, the Breakstone Foods plant in Hagerstown is not unique in its whey disposal practices.

The magnitude of the load that whey places upon a sewage treatment plant can be of course rather large depending on the amount wasted since whey is very rich in readily biodegradeable organic substances. It is estimated that one thousand gallons of whey discharged per day into a treatment plant imposes a BOD loading on that plant equal to the domestic water loading generated daily by 1800 people per day. Thus, in the case of Breakstone Foods plant in Hagerstown, the 8000 gallons of whey discharged per working day by the plant exerts a load on the Hagerstown sewage treatment plant equivalent to the load generated by 14400 people--or 41% of the city's population. Moreover, the wasted curd wash waters of course exert an additional load. Obviously, the load resulting from the whey discharge is relatively large; however, its impact on the municipality's sewage treatment plant was heightened severely because the whey was not released at a steady rate over a 24-hour period but batch discharged to reach the treatment plant in hefty slugs.

(d) Recommended Remedial Action

Upon the conclusion of the survey of the Breakstone Foods plant, the project staff advised city authorities that the severity of the impact of the whey and wash-water discharges on the treatment plant could be ameliorated greatly by having the cheese plant install a simple waste flow equalization tank from which the waste could be bled into the city's sewerage system over a 24-hour period. The city passed this recommendation on to the industry, which immediately responded by taking steps to design and install an appropriate flow equalization system. The project staff, however, requested that the Breakstone Foods delay the installation of any equalization systems until the project was completed to avoid a major change in project baseline conditions while the project was still in progress. This request was honored and no equalization system was installed until after the operational studies of the project were concluded. When an equalization system was finally constructed and placed into operation, an immediate and marked improvement in the performance of the sewage treatment plant was observed by plant personnel.

SECTION VI

STUDIES OF VARIOUS PRETREATMENT METHODS

A. Wastewater Analysis Schedule for Pretreatment Studies

Shortly after the wastewater analyses of the project baseline study were completed and the data compiled and evaluated, a wastewater sampling and testing schedule was prepared for the pretreatment studies of project and submitted to FWQA for review and comment. The schedule was rather ambitious in that it included many more analyses than were originally considered in the project program plan. Tests that were suggested by the findings of the baseline study and that were felt would be of value to the pretreatment studies were added to the original list of proposed analyses. The final schedule, which was designed to meet the sampling and testing requirements of each of the pretreatment studies, is presented on the following pages. Generally, this schedule was fairly well adhered to over the course of the studies.

B. Startup and Stabilization of the Project Facility

On January 27, 1970, the entire wastewater flow received by the Hagerstown treatment plant was directed for the first time into and through the pretreatment tanks of the project facility and the diffused air system of the facility was put into service. Over the following three months--February, March and April--the preaeration of the raw sewage flow was continued to allow the pretreatment tanks of the facility to "stabilize." Although the project program plan called for a one-month stabilization period, which was felt to be sufficient, the initiation of the first pair of pretreatment studies was delayed until certain uncompleted work on the facility, the previously mentioned modifications of the existing final settling tanks of plant Sections No. 1 and No. 2, and the construction of the additional settling tank for these plant sections were completed so that the treatment plant would be fully operational. Throughout the three month period, tests were performed on the influent and effluents of the pretreatment tanks to follow the course of stabilization. Initially, effluent dissolved oxygen concentrations ranged between 7 and 8 mg O_2/l; however, towards the end of February, these concentrations began to drop presumably as a result of the appearance of significant biological growths on the walls of the tanks. By the middle of March effluent dissolved oxygen concentrations were in the range of 4 to 6 mg O_2/l, where they remained until the facility aeration rates were changed in preparation for the first pretreatment study task.

Table 8. ANALYSIS SCHEDULE FOR THE OPERATIONAL STUDIES

Analysis	Type of Sample	Sampling Points	Analysis Frequency	Remarks
Ammonia & Organic Nitrogen	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every 3 Days	
Biochemical Oxygen Demand	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every 2 Days	To be done concurrently with COD's.
Chemical Oxygen Demand	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every 2 Days	To be done concurrently with BOD's, and on both filtered and unfiltered aliquots of samples from points 7A & 7B.
Chlorine Residual	24-hr Composite	2B, 3B, & 7B	Daily	To be done only during pretreatment by chlorination
	Grab	2B, 3B, & 7B	Every 8 hrs Hours	
Color	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every Thursday or Friday	
Dissolved Oxygen	(In Situ Measurement)	1, 2A, 2B, 3A, 3B, 4A11, 4A12, 4A21, 4A22, 4B, 5A13, 5A23, 6A1, 6A2, 6B, 7A, & 7B. Also head and tail ends of all wastewater tanks.	Daily, Week Days	DO Meter measurements made in situ. DO at points 1, 2A and 2B will be measured continuously by automated monitoring system.

Table 8. continued

Analysis	Type of Sample	Sampling Points	Analysis Frequency	Remarks
Hydrogen Sulfide	Grab	1, 2A, 2B, 3A, 3B, 7A & 7B	Daily, Week Days	
Mixed Liquor Microscopic Examination	Grab	5A and 5B	Every Wednesday	
Mixed Liquor Oxygen Uptake Rates	Grab	4A12, 4B, 5A & 5B	Once a Week	Warburg respirometric measurements.
Mixed Liquor Suspended and Volatile Suspended Solids	Grab	4A12, 4A22, 4B, 5A1 5A2, & 5B	Every 2 Days	Sampling point 8 to be included during pretreatment by waste activated sludge addition.
Nitrate	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every 3 Days	To be done every 2 days on samples from points 1, 2A, 3A, and 7A during pretreatment by $NaNO_3$ addition.
Nitrite	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B		
Oxidation-Reduction Potentials	(In Situ Measurement)	1, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B, 6A, 6B, 7A, & 7B	Once a Week	ORP's at points 1, 2A and 2B will be measured continuously by automated monitoring system.

Table 8. continued

Analysis	Type of Sample	Sampling Points	Analysis Frequency	Remarks
pH	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Daily	pH at points 1, 2A, & 2B will be measured continuously by automated monitoring system.
Phosphate (Total)	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every 3 Days	
Sulfate	24-hr Composite	1, 7A, & 7B	Once a Week	To be done turbidimetrically.
"Sulfite" (Iodine Oxidizable Substances)	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every 8 Hours	Analysis measures both sulfide and sulfite concentrations.
Suspended Solids	24-hr Composite	1, 3A, 3B, 7A & 7B	Daily	
Temperature	(In Situ Measurement)	Same as for DO	Daily	To be done concurrently with DO determinations.
Volatile Organics	24-hr Composite	1, 2A, 2B, 7A, & 7B	Every Thursday or Friday	To be done by means of gas chromatography.
Wastewater Oxygen Depletion Rates	24-hr Composite	1, 2A, 2B, 3A, 3B, 7A, & 7B	Every Thursday or Friday	To be done by means of a DO meter.

Table 8. continued

Analysis	Type of Sample	Sampling Points	Analysis Frequency	Remarks
Digester Supernatant Liquor pH, Alkalinity, and Volatile Acids	Grab	Primary and Secondary digester supernatant liquor lines	Once a Week	
Mixed Liquor Settleable Solids	Grab	4A, 4B, 5A, & 5B	Daily	

Notes:

(1) Wastewater Monitoring System to be calibrated every Tuesday and Friday.

(2) Rates at which air, waste activated sludge, chlorine, ammonia, etc., are supplied to the pretreatment tanks to be recorded daily.

(3) Rates at which air is supplied and at which sludge is returned to Sections 1 and 2 and to Section 3 to be recorded daily.

(4) Wastewater flows to the entire treatment plant and to Section 3 contact aeration tank are recorded continuously by existing flow meters.

(5) The wastewaters at sampling points 1, 2A and 2B will be sampled continuously and proportional to the flow by the automatic, refrigerated samplers of the project facility.

Table 9. DESCRIPTION OF SAMPLING POINTS

Sampling Point	Description
1	Influent "Y-Wall" Channel of Pretreatment Tanks
2A	Effluent Channel of Pretreatment Tank A
2B	Effluent Channel of Pretreatment Tank B
3A	Effluent Channel of Primary Settling Tanks 1 & 2
3B	Effluent Channel of Primary Settling Tank 3
4A11	Bay 1 of Section 1 Sludge Reaeration Tank
4A21	Bay 1 of Section 2 Sludge Reaeration Tank
4A12	Bay 2 of Section 1 Sludge Reaeration Tank
4A22	Bay 2 of Section 2 Sludge Reaeration Tank
4B	Section 3 Sludge Reaeration Tank
5A1	Section 1 Contact Aeration Tank
5A2	Section 2 Contact Aeration Tank
5B	Section 3 Contact Aeration Tank
6A1	Effluent Channel of Section 1 Contact Aeration Tank
6A2	Effluent Channel of Section 2 Contact Aeration Tank
6B	Effluent Channel of Section 3 Contact Aeration Tank
7A	Effluent Channel of Settling Tanks of Sections 1 & 2
7B	Effluent Channel of Section 3 Settling Tank
8	Waste Activated Sludge Distribution Box of Pretreatment Tanks

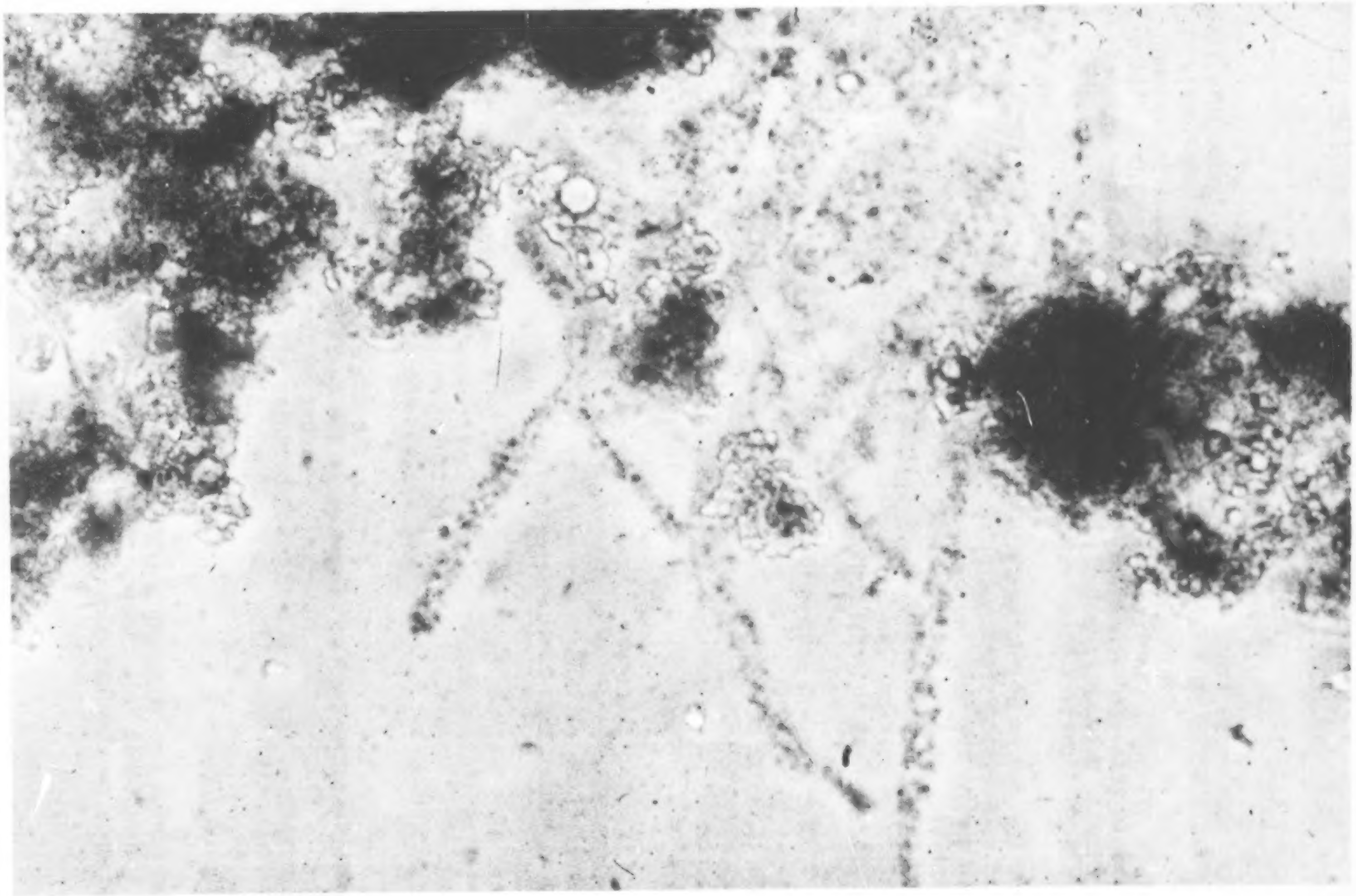

Figure 7. Photomicrograph of the Aeration Tank Mixed Liquors, Showing New Fingerlike Growths of Zoogleal Bacteria

C. Pretreatment by Plain Aeration and by Aeration and the Addition of Waste Activated Sludge

1. General Conditions

This operational study task was begun on 19 May 1970. Under this task, the wastewaters that passed through treatment ystem A (previously referred to as Sections No. 1 and No. 2 of the undivided Hagerstown sewage treatment plant) were pretreated by aeration and the addition of waste activated sludge while the wastewaters that passed through treatment ystem B (previously referred to as Section No. 3 of the undivided treatment plant) were pretreated by aeration alone.

Over the period of the study, the characteristics of the wastewaters that entered the treatment plant remained essentially the same as they were during the baseline study, particularly during May, June, and the first week of July, although the raw wastewaters contained significant amounts of dissolved oxygen, no sulfide and, surprisingly, quite frequently no sulfite. On those rate occasions when sulfite was detected, it was found at concentrations of only 1 mg/l or less.

On 9 July 1970, an extremely heavy rainfall occurred in the Hagerstown area, yielding 4.5 inches of rain from 1600 to 2300 hours. As a result, incoming wastewater flows became abnormally high and remained that way until 20 July 1970. Consequently, on 11 July 1970, the study program of the project was suspended (wastewater sampling being discontinued) and was not started again until 20 July 1970. To make up for the lost study time, the project effort was then extended to 24 July 1970 and therefore spanned a period of 68 days. Rain showers, however, also occurred on 20, 21 and 22 July 1970 to add to area flooding problems and to sustain high flows to the treatment plant and to hamper the pretreatment studies.

These high "wet-weather" flows pointed up a major problem with the city's sanitary sewerage system: Its tremendous susceptibility to storm water runoff. From time to time throughout the life of the project, high wet weather flows plagued the study program.

All through the first study period, the discharging of spent dye stuffs into the sanitary sewerage by the textile dyeing plants in the city continued as was readily evident by the regular week day appearance at the treatment plant of intensely colored wastewaters. Unfortunately, removal by the treatment plant of these colored wastes was not noticeably improved by either of the two pretreatment methods being employed.

Also during the study period, fluctuations in the pH of the raw sewage occurred from time to time with unpredictable and low frequency as they had during the baseline study. The fluctuations were generally no more than ± 1 pH unit and were "smoothed out" by the time the wastewaters passed through the pretreatment tanks. The pH's of most of the raw sewage samples composited daily during the study fell in the narrow range of 7.1 to 7.3; yet, there were daily composites with pH values as low as 6.5 and as high as 8.0.

The BOD_5 of the composite raw sewage samples averaged about 200 mg/l but varied greatly from day to day and, over the study period, ranged from 83 to 403 mg/l. The COD's of the composites also varied considerably, ranging from 296 to 1502 mg/l; their average value for the period was 650 mg/l. The upper limit values of the BOD and COD ranges were obtained on the same sample, which was considered a very typical sample in that it contained an unusual amount of particulate material.

2. Pretreatment by Aeration and the Addition of Waste Activated Sludge. Treatment System A.

Although it had been planned originally to supply air at a constant rate to the pretreatment tank of System A to maintain in the tank fixed conditions with regards to both aeration and mixing and to vary just the rate at which activated sludge was introduced into the tank, the air supply rate was in fact actually changed over the period within the limits of 2.0 to 2.5 thousand cubic feet of air per minute as a consequence of the variations in air supply rates that were effected in System B. Over the study period, the rate at which waste activated sludge was introduced into pretreatment tank A was increased step wise from zero to levels of 9.0×10^4, 1.5×10^5, and 3.0×10^5 gallons of sludge per day. The concentration of suspended solids in the introduced waste activated sludge generally ran about one percent. The maximum sludge feed rate of 3.0×10^5 gph employed during the last weeks of the study created, however, a demand for waste activated sludge that slightly exceeded the capability of the system to generate the waste material. As a consequence of this and the abnormally high stormwater flows that entered the plant during July, the level of suspended solids in the mixed liquors of System A gradually decreased during the final weeks of the study to about 0.5%.

Although preaeration in pretreatment tank A had been effected ever since the start of facility stabilization task, it was not until just before the start of this study, the first of the operational study tasks, that the modifications that were being made in the treatment System A (construction of a new final clarifier and piping changes in the existing final clarifiers) were completed; therefore, preaeration was continued and waste activated sludge was not added to the raw wastewaters entering pretreatment tank A until the third week of the study to allow time to gather some good baseline data on System A. Although it had been hoped that this data would show that System A operated with comparable efficiency to System B,

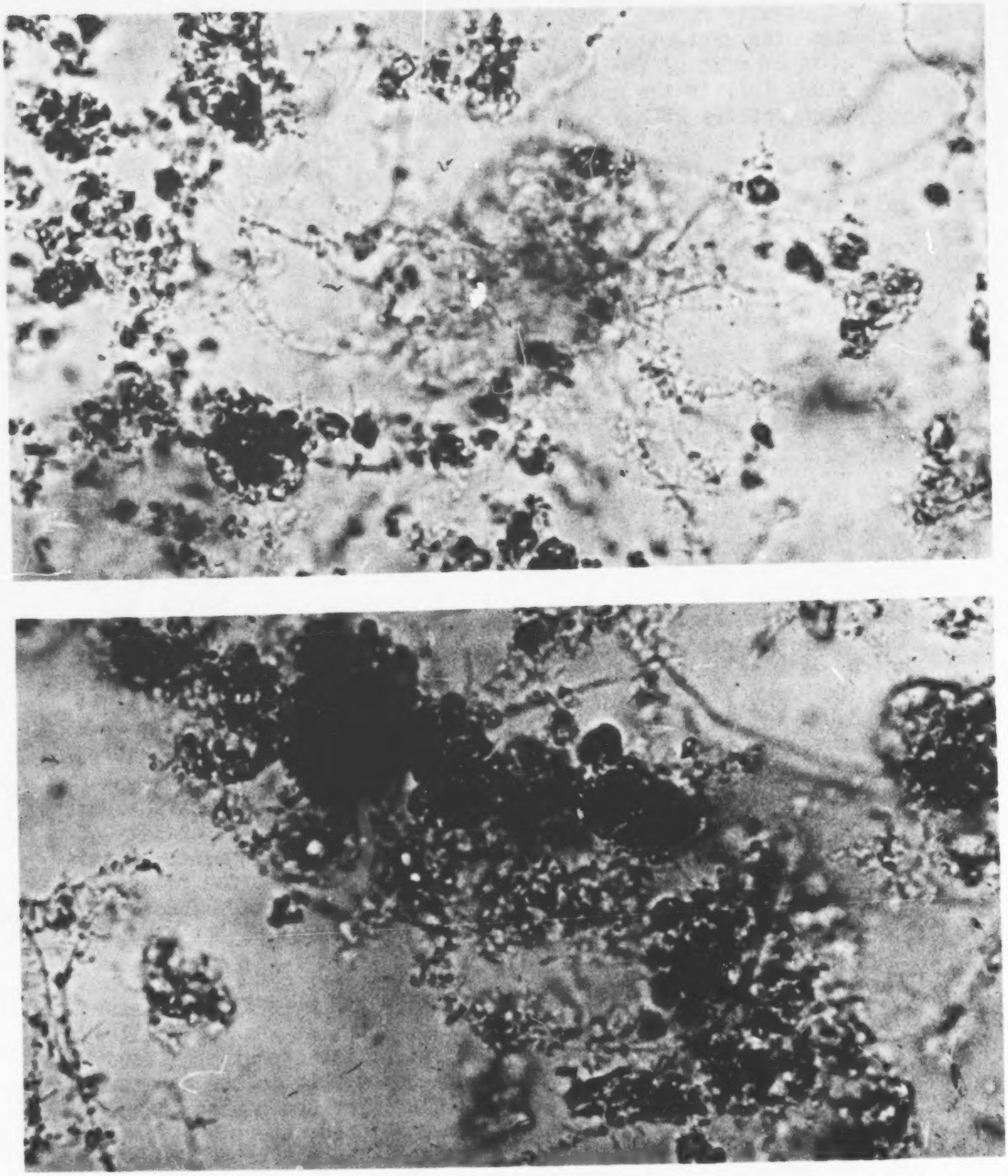

Figure 8. Photomicrographs of the Aeration Tank Mixed Liquors, Taken during the Study of Pretreatment by Addition of Sodium Nitrate and Showing Unidentified Filamentous Bacteria among Small Zoogleal Masses with much Adsorbed Inert Solids and the General "Burnt-Out" Appearance of Overage Sludge Resulting from Excessive Recycling of Biological Solids in the Treatment Plant

significant operation differences between the two systems were found to exist; and these, disappointingly, made the application of the baseline data earlier accrued on the secondary units of System B to the secondary units of System A, unrealistic. One of the major differences noted was that in order to maintain a mixed liquor suspended solids in the contact aeration tanks of System A at the desired level of 2500 mg/l, the sludge reaeration tanks of system a had to carry suspended solids at a level of about 10,000 mg/l; whereas, in System B, the mixed liquor suspended solids in the sludge reaeration tanks needed to be carried at about only 6000 mg/l to achieve the same desired contact aeration tank mixed liquor suspended solids level. This difference was due to the difference in the influent wastewater flow to return sludge pumping rate rates of the two systems. Moreover, it was evident that the air diffusion system of System A (fixed air headers) could not drive as much air into the mixed liquors of System A on a per volume basis as the air diffusion system of System B could drive into the mixed liquors of System B.

As a consequence of these two differences, treatment System A did not function as well as treatment System B under similar conditions. While pretreatment by aeration alone was being carried out in both systems, hydrosulfuric acid, H_2S, was found frequently in the sludge reaeration tanks of System A but found only very rarely in the sludge reaeration tanks of System B. And, frequently during this study, the H_2S concentrations were observed to build up in the sludge reaeration tanks (to levels over 5 mg/l) then spill over and load the contact aeration tanks of System A. Of course, during the baseline study, when preaeration was not practiced, H_2S appeared quite regularly and in great abundance throughout the entire plant, being found in the wastewaters of the primary settling tanks, the sludge reaeration and contact aeration tanks, and final settling tanks. In this pretreatment study, this chemical species appeared with any regularity in only the sludge reaeration tanks of System A.

In order to avoid sweeping the malodorous H_2S gas from the sludge reaeration tanks into the atmosphere in such quantities as to annoy the public, chlorination of System A return sludges was practiced intermittently, over the lifetime of the study task, at critical times (normally from early evening to early morning, 1600 to 0200 hours) but not at times, it is believed, that would affect test results. Of course, this odor control practice did not permit the research team to discover just how great the hydrosulfuric-acid-hydrogen-sulfide-gas build up could become and, consequently, could heighten treatment difficulties under each new operational condition tried. However, scientific curiousity withstanding, consistent H_2S production in a system intended to function aerobically is, without question, in itself, symptomatic of unsatisfactory system performance no matter how far it is allowed to proceed. So, it was felt that project objectives were not subverted by limiting H_2S production and that the additional data that perhaps could have been gathered had chlorination of the return sludges not been practiced would not be of sufficient value to the project to risk arousing public ire in trying to get them.

Some of the data that was obtained in the study on pretreatment by aeration and addition of waste activated sludge are presented in the tables in the Appendices. The data shows that pretreatment by air and waste activated sludge addition did improve the performance of System A but show, in addition, that the resulting performance was, generally, irregular and rather disappointing. Yet, there appears in the data a trend of increasing improvement with increasing sludge addition, the average percent daily BOD removal reaching 79% during the period in which the sludge feed rate was at its maximum. Unfortunately, however, the existence of this trend is somewhat obscured by the uncertainty of what effects the high hydraulic overloads experienced by the plant toward the end of the study had on study results.

3. Pretreatment by Plain Aeration. Treatment System B

The air supply rate to the pretreatment tank of System B was varied over the study period from 1.0 x 10^3 to 3.5 x 10^3 cubic feet of air per minute. For a wastewater flow of 2.5 mgd (the assumed average flow for the study), this variation amounted to a variation in air application of 0.58 to 2.0 cubic feet of air per gallon of wastewater. Initially, it had been planned that the air supply rate be increased in steps every two weeks with the excess air generated by the constant speed positive displacement blowers being bled off through the pressure relief valves of the blowers themselves. However, for certain selected air supply rates, it was found that the relief valves were not capable of bleeding off the high surpluses of air generated. As a result, the air supply rate was not constantly increased in regular steps over the entire period of the study but was increased directly from the minimum rate tried initially to the maximum rate tried and then decreased to an intermediate rate which was achieveable only after a special air release valve (gate valve) was installed in the air main.

Over the first two-week period of the study, pretreatment tanks B received air at the 1.0 x 10^3 cfm rate and the daily BOD removals by the system averaged 84%. For those study periods that followed in which higher preaeration rates were employed, the averages of the percent daily BOD removals were less than 84%. Specifically, for those subsequent periods in which the air supply rates used were 2.5 x 10^3 cfm and 3.5 x 10^3 cfm the average BOD removals were only 79 and 78%, respectively. The dissolved oxygen concentration in the pretreatment tank effluent increased with the stepped increases in preaeration rate, going from an aeration step period average of 1.1 mg/l for 1.0 x 10^3 cfm air to 5.6 mg/l for 3.5 x 10^3 cfm air. However, the primary tank effluent dissolved oxygen level did not change markedly over the study in the changes in the preaeration rate, the dissolved oxygen level in the primary effluent generally staying below 1 mg/l.

Because it seemed inexplicable that better treatment would be obtained with only 1.0×10^3 cfm of air being applied in pretreatment and not with the greater air applications, preaeration with 1.0×10^3 cfm air was tried again during the final weeks of the study task. This time, the daily BOD removal percentages were greater than before, their average being 93%. The high flows created by the wet-weather conditions that prevailed during this latter period clouded the analytical picture somewhat and it is difficult to say for certain why this particular improvement was observed.

Although System B showed significant improvement in effecting treatment with pretreatment by aeration, the almost consistent appearance of rather low dissolved oxygen levels in and ORP values of the liquors of the sludge reaeration and contact aeration tanks strongly indicated that these units were at best just barely able to supply sufficient oxygen to meet the exerted oxygen demands.

Perhaps, one of the most encouraging signs of treatment improvement in both Systems A and B, which had been noted ever since the pretreatment facility was brought into service and preaeration was begun, was the reduction in the amount of suspended matter in the final plant effluent. During the baseline study, final effluent suspended solids levels as determined on 24-hours composite samples were generally above 100 mg/l and sometimes approached 200 mg/l. After the baseline study, when preaeration was practiced, effluent suspended solids levels fell well below 100 mg/l--particularly in System B.

These data as well as the data mentioned earlier and other pertinent analytical results that were gotten during the study task are also tabulated in the Appendices of this report.

4. Improvements in Plant Biota

In general, it was noteable that, as a result of both pretreatment methods employed, there were improvements in the quality of the wastewaters being introduced into the mixed liquor basin and in the performance of the basins themselves. These improvements appeared despite the heavy hydraulic overloads caused by the heavy rains in the Hagerstown area. It was particularly striking that the sulfur precipitating bacteria that had been present during the baseline study were absent during this study from the various aeration tank mixed liquors and from the water of the preaeration tanks, and that new fingerlike growths of zoogleal bacteria were common in the mixed liquors. (See Figure 7.). *Microbiologically, these findings represented a distinct improvement over the conditions prevailing in the treatment plant before pretreatment was applied.*

D. Pretreatment by Addition of Sodium Nitrate and by Addition of Ammonia

1. General Conditions

During the approximately eight-week period of this study, as a result of little rainfall in the Hagerstown area, the treatment plant did not experience the high hydraulic overloads that it had during the latter part of the preceding study. Daily total flows recorded at the plant varied from 4.1 to 6.8 million gallons. Thus, daily flows stayed well under the 7.5 mgd design average hydraulic load capacity of the plant. The average flow for the period was only 5.35 million gallons daily.

Sulfite, which had been associated with the discharge into the city's sewerage system of spent liquors from the dye-stripping operations of the textile dyeing plants located in the city, was rarely detected in the raw wastewaters although the consistent appearance at the treatment plant of intensely colored waters affirmed that the dyeing plants continued to operate and to discharge dyeing wastes throughout the study. And, with the exception of only a few cases in which readings of 0.1 and 0.2 mg H_2S/l were obtained, hydrogen sulfide concentrations in the raw wastewaters were generally zero. In addition, the dissolved oxygen levels in these waters were found to be lower than they had been throughout the preceding study assumably, as a consequence, of reduced stormwater inflow and infiltration during this study. Over the study period, the raw sewage dissolved oxygen concentrations ranged from 0.3 to 1.6 mg O_2/l with an average for the period of 0.6_8 mg O_2/l.

The pollutional strengths of the raw wastewaters as determined on 24-hour composite samples ranged from 63 to 528 mg BOD_5/l and 338 to 1886 mg COD/l with the averages for the two sets of measurements being 262 mg BOD_5/l and 1040 mg COD/l. The lowest BOD_5 and COD values and the highest BOD_5 and COD values were obtained, as might be expected, on the same samples.

A number of unusually high pollutional strength raw wastewater samples were obtained at different intervals during the study but their high pollutional strengths were the result of materials introduced into the raw wastewaters by the treatment plant itself. The filamentous sulfur bacteria that were discovered in the plant during the baseline study and that subsequently disappeared from the plant during the first pretreatment study remained absent from from the plant during this study. However, early in this study, a new and different type of filamentous microorganism appeared throughout the plant. This organism was of the kind sometimes noted in "overaerated" or underloaded extended aeration activated sludge systems. Photomicrographs of the Hagerstown sewage treatment plant mixed liquors containing these organisms are presented in

Figure 8 on the next page. The bacterial filaments are sheathed with a very sticky, watery stuff to which small zoogleal masses readily adhere; and, thus, they form biological mats that settle poorly and are easily buoyed by microscopic bubbles or adsorbed oils. Consequently, these filamentous growths that developed in the plant created a biological sludge that would not settle well in either the aeration basins or, when wasted, in the anaerobic digesters. As a result, waste activated sludge eventually would be returned to the head of the treatment plant via the digesters with the drawn-off digester "supernatant liquor," increasing the pollutional strengths and the suspended solids levels of the raw wastewater samples.

By 11 September 1970, this undesirable recycling of biological solids caused such a buildup of suspended solids in plant and generated such a heavy organic load on the plant that treatment System A, which was having difficulty providing sufficient air to its aeration basins even under "normal" loadings, began to produce in its aeration basins and to release from there to the atmosphere considerable amounts of hydrogen sulfide gas and the sludge in the final clarifier of treatment System B began to bulk severely. The odor problem became intolerable on 17 September 1970 and around-the-clock chlorination of System A return sludges had to be executed to abate the intense pungent odor of H_2S that was being produced and creating much public annoyance. On 21 September, the suspended solids level in the daily composite raw sewage samples was over 1300 mg/l. On 22 September 1970, in order to stop the constant cycling and buildup of biological solids in the treatment plant, the uncovered digester tank of the plant was placed into service to receive and store the heavily suspended solids laden digester supernatant liquors. Although it was hoped that, in the open tank, the suspended matter could be made to settle out by chemical means, through addition of ammonia gas to raise the pH of the held liquors to above 8.5, effective solids separation was never achieved. However, the use of the tank to store the digester liquors temporarily broke the sludge recycling cycle and relieved the plant of its self-generated overload.

As a result, this difficulty with suspended solids recycling in the plant did not become troublesome again until two to three weeks later; and, at that time, it was compounded by the occurrence of rising sludge (believed to be caused by denitrification) in the primary settling tanks of System A. Furthermore, at the end of the study period, with relatively high concentrations of digester solids again coming into the plant proper, a gas was noticed evolving from the primary tanks of both Systems A and B. A sample of this gas was collected and analyzed in the laboratory by means of gas chromatography and found to be a mixture of methane (62.5%), nitrogen (37.0%), and oxygen (0.5%). This information thus indicated that a sizeable amount of methane-forming bacteria has been swept from the digesters and deposited in the primary tanks. Fortunately, during the two-week "change-over period" that followed the termination of the pretreatment study the solids problem abated and the treatment system gradually returned to its baseline conditions.

2. A Search for the Cause of the Appearance of the Filamentous Organism

Because the filamentous bacteria that produced the poorly settling sludges had been seen before by members of the project team in only "overaerated" or underloaded extended aeration sewage treatment plants, it was felt that (1) they may be saprophytes of the mixed liquor zoogleal bacteria--that is, that they may utilize for substrate the walls zoogleal masses and other generally refractory materials of lysed zoogleal cells--and thus become populous in underloaded systems or (2) they may be a direct consequence of nitrate additions to the wastewaters (or the relatively high nitrate concentrations produced in extended aeration treatment systems exceeding having long aeration periods). A laboratory experiment involving aeration for several days of an unfed sample of the Hagerstown treatment plant mixed liquors containing the filamentous bacteria and no nitrate was carried out under the direction of the project biologist in order to test the first hypothesis, i.e., to see if the filamentous organism would proliferate under truly extended aeration conditions. They did not, and so it was concluded that they were indeed not saprophytes of the zoogleal bacteria. No effort unfortunately was ever made by members of the project team to rigorously test the second hypothesis although it was hoped that such a test could have been made before the project was terminated.

3. Pretreatment by Addition of Sodium Nitrate

Under this operation study of the project program, sodium nitrate (Chilean nitrate, 16% nitrate nitrogen) was added to the raw wastewaters that were directed through treatment System A of the divided treatment plant. The initial rate of addition was 250 lbs of sodium nitrate per day, and this rate was subsequently doubled every two weeks over the eight-week period of the study. Thus, sodium nitrate feed rates of 250, 500, 1000, and 2000 lbs/day were employed. For a wastewater flow of 5 mgd--the flow that had been anticipated for the treatment system--these feed rates would have yielded nitrate-nitrogen concentrations in the wastewater flow of roughly 1, 2, 4 and 4 mg/l, respectively. However, over the study period, System A flows ranged from 1.9 to 4.1 mgd and averaged 2.9 mgd; therefore, nitrate-nitrogen concentrations that were introduced into the wastewaters were on the average 1.7 times greater than planned.

The sodium nitrate was added to the wastewaters at the head end of the pretreatment tank of System A and this tank was aerated with air supply rates being maintained at about 1400 ± 300 cfm over the study period to promote mixing as well as to keep particulate matter in suspension. The sodium nitrate was fed to the wastewaters in solution form by the dry chemical feed machine of the project facility except when the feed rate was 2000 lbs/day. This feed rate exceeded the feed rate capacity of the feed machine; and, consequently, the output of the feed machine had to be supplemented by manually adding sodium nitrate to the wastewaters in order to achieve the desired feed rate.

As expressed in terms of BOD_5 removal, the degree of treatment obtained in the treatment system did not increase consistently with increasing nitrate feed rates, although the highest average percentage BOD_5 removal, which was 85%, for any two-week period of the study was realized for that two-week period in which the sodium nitrate feed rate was at its maximum, 2000 lbs/day. Yet, because of the high levels of suspended solids that were in the system at this time and which added more to the COD than to the BOD values of the wastewaters, the average percent BOD removal for the same period was only 51%, which is far lower than the average percent COD removal for any preceding two-week period. On the other hand, however, the daily percent removals of suspended solids over the entire study period were of course much higher than previously experienced with the overall average for the period being 91%.

Within a week after the sodium nitrate feed rate was increased to 2000 lbs/day, during a period when considerable quantities of activated sludge were being wasted into the pretreatment tank of System A in hopes of alleviating the previously mentioned problem of high suspended solids levels in the treatment plant, sludge began rising in the primary tanks of System A--but not in the primary tanks of System B. Consequently, on 8 October 1970, the nitrate feed rate was reduced for two days to 8 lbs/day, and the formation in the primary tanks of a sludge-scum blanket subsided. The nitrate feed rate was then increased to 2000 lbs/day again, and again a thick (6-inches deep) sludge-scum layer formed on the surface of the wastewaters in the primary tanks of System A, evidently as a result of denitrification.

Only during that time when sodium nitrate was being added to the wastewaters at the maximum rate employed where appreciable nitrate-nitrogen concentrations detected in the effluent from the pretreatment tank. At the lower feed rates, nitrate-nitrogen concentrations in the pretreatment tank effluent were generally below 0.2 mg/l. Since the nitrate nitrogen that disappeared in the pretreatment tank did not reappear in the system as either ammonia, organic, or nitrite nitrogen to any significant extent, it is believed that the reduction in nitrate concentrations in the system was a result of the biological utilization of nitrate as a hydrogen acceptor ("chemical oxygen source") rather than as a nitrogen source, with the concomitant loss of nitrogen as N_2.

The more significant experimental data obtained in this pretreatment method study can be found tabulated in the appendices of this report.

4. Pretreatment by Addition of Ammonia

In this study, ammonia was added to the raw wastewaters that were passed through treatment System B of the divided treatment plant, with the point of ammonia introduction being at the head end of the pretreatment tank of System B. Initially, anhydrous ammonia from manifolded 150-lb cylinders was fed by means of the ammoniator of the project facility in ageous solution form; however, after several weeks of study time had elapsed, direct feeding of gaseous ammonia into the wastewaters had to be resorted to because the hydraulic ejector assembly of the ammoniator became so severely clogged by heavy scaling that ammonia feed rates above 60 lbs/day could not be attained. Direct feed was accomplished by temporarily modifying the ammoniator in a manner that enabled the machine to still regulate and measure gas flows, while ammonia was being withdrawn under pressure instead of under a partial vacuum.

The initial ammonia feed rate used was 30 lbs of ammonia per day. For the wastewater flow that had been anticipated for the treatment system--VIZ., 3 mgd--this feed rate would have increased the ammonia-nitrogen concentration in the wastewaters (which, incidentally ran about 15 ± 5 mg NH_3-N/l) by only slightly more than 1 mg/l. Ammonia feed rates were doubled every two weeks at the same time the nitrate feed rates were doubled in the concurrent pretreatment study; thus, ammonia feed rates of 30, 60, 120 and 240 lbs/day were utilized in the study. To insure accuracy of gas flow measurements, the rotameter of the ammoniator was checked frequently by directly weighing the ammonia cylinders to determine their losses in weight in a given period of time, usually 24 hours.

Air was also introduced into the pretreatment tank of System B, the introduction of course being made through air diffusion system of the tank. As in the case of pretreatment by nitrate addition, aeration was carried out to keep particulate matter in suspension and to mix the wastewaters with the ammonia feed. Air supply rates to the pretreatment tank were maintained at 2000 ± 500 cfm over the lifetime of the study.

Although it had been anticipated from the wastewater flow data that was obtained during the preceding study task that System B wastewater flows would be about 3 mgd during this study, wastewater flows in System B were actually less than that value for the study, ranging from 2.1 to 2.9 mgd with a study average of 2.4 mgd. Even though these flows were less than anticipated, they all exceeded the design average hydraulic load capacity of the secondary units of System B of 2.0 mgd. Yet, the treatment system generally effected fair to good treatment over the study period.

The average percent removals of BOD_5 realized for each of the four different ammonia feed rate periods were: 90% (30 lbs NH_3/day), 89% (60 lbs NH_3/day), 80% (120 lbs NH_3/day), and 95% (240 lbs NH_3/day) while the percent COD removals for these same periods were: 89% (30 lbs NH_3/day), 88% (60 lbs NH_3/day), 78% (240 lbs NH_3/day). Moreover, over the entire study, the daily percent suspended solids removals were usually in the 90's to give an overall average removal of 95% for the study period.

All these figures indicate improvement in treatment in System B over the treatment that was realized during both the baseline and preceding pretreatment studies. However, the effect of the lower wastewater flows and, particularly, the solids problem experienced in this study on the removal percentages was indeed significant and even may have obscured the full treatment benefits that may be deriveable from ammonia addition.

Additional data obtained in this study are listed in tables that may be found at the end of this report.

E. Pretreatment by Addition of Potassium Permanganate and by Addition of Chlorine

1. General Conditions

This study, like the immediately preceding treatability study, was conducted over a period of about eight weeks. Specifically, the study was initiated on October 30, 1970, and concluded on December 26, 1970. Dry weather conditions prevailed for nearly the entire time and, except for the final four days of the study period, influent flows ranged from 4.6 to 8.2 mgd and averaged 6.4 mgd, which is below the 7.5 mgd average design flow for the plant. During the last four days of the study, high rains swelled the waste flows from 9.8 to 19.7 mgd.

The BOD_5's of daily composite samples of the raw sewage ranged from a low of 82 to a high of 372 mg/l and averaged 186 mg/l while the COD's of these same samples varied from 307 to 1334 mg/l and averaged 671 mg/l. These BOD and COD averages are less by about one third than the corresponding BOD and COD averages of the first operational study. In addition, plant influent suspended solids concentrations, which were also measured on the 24-hour composite samples of the raw sewage, ran from 40 to 800 mg/l and averaged only 350 mg/l. Thus, the average values for BOD, COD and suspended solids concentrations over the period apparently show that, as far as these parameters are concerned, the quality of the raw sewage had returned essentially to baseline characteristics during this study; yet, however, over the first week of the study period, the concentration of suspended solids in the raw sewage and, concomitantly, the COD of the raw sewage were consistently higher than the respective averages for the study period evidently as a result of the system having not yet fully returned to baseline conditions from the unusual solids problem created in the preceding study.

As in all the preceding studies, the highly colored wastes from the textile dyeing plants constantly entered the treatment plant on week days throughout the study period. And, during the first 3 to 4 weeks of the study period, the level of sulfite and raw sewage usually stayed at around 1 mg/l although it did drop to a low of 0 mg/l and rose to a high of 2 mg/l. But, over the remaining 4 to 5 weeks of the study, even though wasted dyestuffs continued to enter the plant as before, no sulfite was ever found in the raw sewage. Moreover, throughout the entire 8-week study period, no suflide was ever detected in the plant influent or in any part of the treatment system. In addition, only on one day out of the entire eight weeks of the study was there no dissolved oxygen found in the raw sewage; otherwise, raw sewage dissolved oxygen concentrations fell in the range of 0.3 to 4.8 mg/l with 1.7 mg/l being the mean dissolved oxygen concentration value of the raw sewage for the study period.

F. Pretreatment by Addition of Potassium Permanganate

By means of the dry chemical feed machine that had been employed in the previous study for feeding sodium nitrate, potassium permanganate was added to the wastewaters being channeled into pretreatment tank A. The chemical was applied as an aqueous solution at rates of 20, 40, 80 and 160 lbs/day with each rate being tried in the sequence given for a two-week period. Except for the last four days of the study, daily waste flows through treatment System A remained fairly constant, staying within 4.5 ± 1.1 mgd. Based on the 4.5 mgd flow, potassium permanganate doseage rates were then 0.53, 1.1, 2.1, and 4.2 mg/l, respectively, for the four feed rates utilized. Pretreatment tank A was aerated with about 2000 cfm of air to insure good mixing of the chemical with the wastewater.

Best treatment of the wastewater by treatment System A in terms of the average percent COD removal for a particular two-week doseage period was achieved during the first two-week period when the permanganate feed rate was just 20 lbs/day. The average percent BOD removal for the system during the two-week period was 83%. However, in terms of percent BOD_5 removal, treatment during the first two-week period by the system was erratic and no better than the two subsequent two-week doseage periods with the average percent BOD_5 removals for all three periods being about 75%. The average percent BOD removals for the second and third two-week doseage periods (when feed rates were 40 and 60 lbs/day, respectively) were 65 and 66%, respectively. Treatment deteriorated significantly in the system during the final two-week period, owing to the greatly increased wastewater flows and resulting relatively high solids carry over in the final effluent of the system. The averages of the daily percent BOD_5 and COD removals for the final period were only 69% and 62%, respectively. For this same period, suspended solids removals averaged only 54%. In fact, the average percent suspended solids removals for the various doseage periods consistently decreased from the first period to the last with the percent removals for the first, second and third periods being, respectively, 86%, 82% and 71%.

Although the highest average percentage COD removal for any two-week period during the study occurred during the first two-week period when permanganate was being added at a rate of 20 lbs/day, it seems from the experimental data that this improvement was more apparent than real, resulting from mainly high influent COD's caused by a typically high influent suspended solids levels rather than as a direct effect of permanganate addition. BOD_5 removals, which would not be as greatly effected by high suspended solids levels in the plant influent, were not necessarily better for this two-week period than for any other of the study nor, in fact, was the quality of the final effluent of treatment System A. Therefore, it appears reasonable to conclude that the potassium permanganate additions produced no measureable improvement in the performance of the treatment system.

2. Pretreatment by Chlorination

While the wastewaters coursing through treatment System A were being pretreated by addition of potassium permanganate, the wastewaters in System B were being pretreated by chlorination. As with the sodium nitrate additions, one chlorine doseage rate was tried for a single two-week period, then doubled the next second week period and so on over the four two-week periods of the eight-week study. Chlorine was initially applied at 150 lbs/day, then increased to 300, to 600 and finally to 1200 lbs/day. Wastewater flows in System B for the first 31 days of the study averaged 1.45 mgd and ranged between 1.0 and 1.8 mgd. For the final 25 days of the study--except for the very last 4 days when flows rose and varied between 3.2 and 5.0 mgd in System B due to the contribution of the previously mentioned stormwater runoff flows--wastewater flows increased suddenly, averaging 2.4 mgd and ranging from 2.2 to 2.7 mgd. In any event, by calculation, the chlorine doseages for the various feed rates and the average flow values were approximately 12, 24, 30 and 60 mg/l, respectively.

As in the parallel study of pretreatment by addition of potassium permanganate, the best treatment obtained in terms of COD removal by prechlorination of the raw sewage was realized during the first two-week period of the study during which time the chlorine feed rate was 150 lbs/day; the average percent COD removal for the entire two weeks was 90%. But, unlike the situation that developed in the permanganate study, percent BOD_5 removals achieved by System B for the period were also high and consistently so, their average being 93% and their value range, 89% to 98%. Moreover, except for one day when the percent suspended solids removal obtained was unusually low, 73%, the daily percent suspended solids removals too were high. They averaged 97% exclusive of the 73% removal value and the average of the suspended solids concentrations in daily composites of the final effluent were just 4 mg/l.

Over the three succeeding two-week study periods, the individual period averages of the daily percent removals of all three wastewater parameters--BOD_5, COD, and suspended solids--consistently decreased from one two-week period to the next. This trend can be seen in the table of percent removal values given below.

TABLE 10. AVERAGE PERCENT REMOVALS OF BOD_5, COD AND SUSPENDED SOLIDS ACHIEVED FOR THE FOUR TWO-WEEK PERIODS OF THE STUDY OF PRETREATMENT BY CHLORINATION

Pretreatment Period	Chlorine Feed Rate (lbs/day)	Removals		
		%BOD	%COD	%SS
1	150	93	90	97
2	300	84	71	90
3	600	73	65	76
4	1200	69	61	74

Shortly after the chlorine feed rate was increased to 600 lbs/day to initiate the third two-week study period, chlorine residuals of the order of 0.5 to 1.5 mg/l were frequently detected in grab samples of the effluent of the primary tank (i.e., influent of the contact aeration tank) of System B. When the feed rate was subsequently increased to 1200 lbs/day, chlorine residuals in grab samples of the primary effluent were regularly detected and ranged as high as 1.5 to 5.0 mg/l; furthermore, chlorine residuals were detected for the first time, although in trace amounts, in the effluent from the aeration basin. General experience has shown that, while even very high doseages of chlorine applied directly to the liquors of aeration tanks for rather short periods of time may exhibit no appreciable effect on the performance of the tanks, the continuous maintenance over an extended period of time of even relatively low chlorine residuals in a mixed liquor basin can adversely effect the performance of the basin. Consequently, it is believed that the frequent to almost constant appearance of chlorine residuals in the influent of the aeration tank of System B during the last 4 weeks of the study contributed to the decrease in the degree of treatment achieved by the system. During the last 4 weeks of the study and particularly the last two, bleaching of suspended matter in the wastewater flow was readily apparent and the odor of chlorine readily detectable throughout the treatment system.

G. Pretreatment by the Select Method

As mentioned earlier, the final operational study task of the project involved the application of the pretreatment process revealed by the preceding studies to be the most effective in treating the wastewaters to all the incoming raw sewage and required the recommendation and utilization of the entire sewage treatment plant. Thus, upon the completion of the final pair of pretreatment studies, data obtained from all six studies was reviewed; and it was concluded that prechlorination carried out at the rate of 150 lbs of chlorine per day per 2 mgd of flow had yielded the best treatment results and that this doseage, the lowest tried, was probably more than sufficient since the degree of treatment that was realized had actually dropped off with the higher chlorine doseages employed. Moreover, one important question remained to be answered: How significantly had the dry-weather flow conditions that existed at the time prechlorination was investigated at the 150 lbs/day feed rate enhanced the goodness of treatment? Consequently, prechlorination was selected at the pretreatment method to be applied to the entire incoming raw sewage flow of the Hagerstown treatment plant.

The high flows that occurred during that last week of the final pair of pretreatment studies lasted through the month of December and into January. Although the "change over", i.e., recombination of treatment systems A and B, was effected quickly by simpled valve changes, prechlorination of the entire plant influent was not begun until January 18, 1971, in hopes the high incoming flows would subside. Unfortunately, they did not; but, nonetheless the final study was begun on January 18th since the project program had already fallen considerably behind schedule by that time.

Chlorine was applied to the waste flow at a selected rate of 300 lbs/day for the entire duration of the study, which was 68 days. Except for nine days in early February when flows ran between 5.9 and 7.4 mgd, all daily flows exceeded the design hydraulic loading of the treatment plant. The average of the daily flows for the 68-day period was 9.0 mgd. Thus, the applied chlorine doseage based on this average flow value amounted to only 4 mg/l.

The constantly high wastewater flows through the aeration and final settling tanks of the treatment plant swept biological active solid from these tanks and out of the treatment plant. Consequently, the maintenance in the contact aeration tanks of reasonable biomass was difficult; in fact, contact aeration tank mixed liquor suspended solids levels dropped to 600 mg/l and even lower on several occasions during the study period. As a result, treatment suffered appreciably. For fourteen days scattered throughout the study period, final effluent suspended solids level exceeded influent suspended solid levels; and the daily percent suspended solids removals for the remaining 54 days of the study averaged only 57%. However, for these 54 days, the average concentration of suspended solids in the final effluent was 55 mg/l, which, although high, was not as high the value obtained during the baseline studies. The daily percent BOD_5 and COD removals were very poor, their averages for the period being 63% to 53%, respectively, and they varied widely from one day to the next as can be seen from the data presented in the appendices.

During the last week in January filamentous organisms appeared in moderate numbers in the mixed liquor of only the aeration tanks of old system B and they persisted for no longer than two to three weeks. They were identified as being to the genus *Sphaerotilus* and were definitely not the same filamentous organism that was prevalent in the plant during the baseline studies nor during ammonia and nitrate addition studies. In any event, they apparently diminished the settleability of the biological floc since floc particles were swept readily from the plant by the high wastewater flows. In general, however, the biomasses in all the various aeration basins of the treatment plant appeared to be highly stabilized, containing many stalked ciliates of the *Vorticella* microstomas species and young zoogleal masses of bacteria.

Needless to say, the results of the study were extremely disappointing, but they served to emphasize the city's great need to minimize the inflow of stormwaters into the sanitary sewerage system.

H. Sludge Dewatering Experiments

As part of the final operational study task of the project program, the ease with which digested sludges and undigested waste activated sludges that were produced in the treatment plant during the testing of the select pretreatment method could be dewatered was to be investigated. Thus, prior to the start of the final study task an empty plant digester, Digester No. 4, was readied for service; and, shortly after the study was begun, when it was felt that "steady-state" conditions in the treatment had been established, the prepared digester was placed into operation, receiving and digesting sludges in accordance with usual plant practices. The digester was brought relatively rapidly into operation by means of the conventional procedure for reactivating a "stuck digester" (2), although some delay was experienced due to the inability of the digester heating system (which had fallen in a state of disrepair) to adequately maintain proper digester temperature, 95 ± 3°F. The sludges introduced into the digester were a combination of primary and waste activated sludges withdrawn from the primary settling tanks of the treatment plant.

One of the sludge dewatering studies undertaken was of the ease with which sludges from Digester No. 4 and undigested waste activated sludges from the aeration basins of the treatment plant could be dewatered on a vacuum filter; and, a second study was of the ease with which just Digester No. 4 sludges could be dewatered on sand beds. The vacuum filter utilized in the first study was a Komline-Sanderson 3' x 1' pilot "Coilfilter" with 10 square feet of filter area made of stainless-steel coil springs.

The sludges dewatered on this vacuum filter were first conditioned with chemicals; namely, ferric chloride, lime, and/or a commercial polymer preparation known as Floculate #532, manufactured by the DuBois Chemical Co. Conditioning varied from treatment with ferric chloride (10% solution) and lime (10% solution) to treatment with a mixture of polymer, ferric chloride and lime. Preliminary laboratory tests on the sludges determined the chemical requirements which produced the best filter cake for the types of sludges to be filtered.

The results of the vacuum filtration experiments showed that the digested waste activated sludges, on the whole, had a slightly lower moisture content, 73 ± 8%, than the undigested or raw wastes activated sludges tested, 76 ± 6%, when preconditioned with ferric chloride and lime. Little improvement in moisture reduction was realized when a polymer was included in the preconditioning process, 71 ± 4% for the undigested sludges and 71 ± 5% for the digested sludges tested. However, these moisture contents are within the range of typical sludge filter cake--70% to 80% by weight. The water content in these dewatered sludges lend them satisfactory for short distance hauling to a landfill for final disposal.

An important measure of the efficiency of the filtration process is of course the filtrate quality. The clarity of the filtrate is an indirect measure of the efficiency of solids recovery, since these solids which are not recovered in the sludge cake are discharged to the filtrate stream. In the experiments performed under this investigation the percentage of solids remaining in the filtrate ranged from 1 to 3% for digested sludges treated with $FeCl_3$ and lime to 2 to 21% for raw sludge treated with the same chemicals. Addition of the polymer compound (Floculate 532) in pretreatment of the sludges seems to have improved the filtrate quality of the raw sludges seems to have improved the filtrate quality of the raw sludge filtrates; however, the limited amount of data available for this experiment casts doubt on the certainty of this conclusion.

Overall, the digested sludges exhibited slightly better qualities of the two types of sludges tested by vacuum filtration, as is generally true.

As mentioned, also tested under the sludge dewatering task was the dewatering of digested sludges on a sand bed. Three separate beds were set up; one containing a 4-inch deep layer of sludge; another, an 8-inch deep layer of sludge; and yet another, a 10-inch deep layer of sludge. The results of this investigation showed that dewatering of the digested sludge to a moisture content comparable to that for the same type of sludge dewatered on a vacuum filter required 4 to 5 days for the 4-inch thick sludge layer, 7 to 8 days for the 8-inch thick sludge layer, and about 10 days for the 10-inch thick sludge layer.

Table 11. THE DECREASE WITH TIME IN THE PERCENT MOISTURE CONTENT OF DIGESTED SLUDGE PLACED ON SAND DRYING BEDS IN VARIOUS LAYER THICKNESSES

Date	% Moisture Content for Various Thicknesses of Sludge Layers		
	4"	8"	10"
4/15/71	78.2	81.1	82.6
4/17/71	77.4	83.8	82.5
4/19/71	70.3	78.8	79.0
4/20/71	67.6	78.0	78.4
4/21/71	--	76.5	75.4
4/22/71	--	74.1	75.6
4/23/71	--	64.8	62.2
4/26/71	--	67.6	70.2
4/27/71	--	--	70.7

SECTION VII

SUMMARY

A. General

Much effort, well beyond the scope of the original project plan was expended to define as accurately as possible the causes and to develop practical solutions to the problems faced by the City of Hagerstown in the treatment of its combined domestic-industrial wastewaters. The original analytical schedule of the project program plan was expanded, additional survey tasks undertaken, and operational studies extended to obtain more complete information and to insure the achievement of project objectives.

As a result of the project, it was clearly shown that the municipal treatment plant suffered from severe hydraulic overloading during wet-weather conditions and organic overloading from periodic slug discharges of cottage cheese whey from a local cheese manufacturing plant. It was revealed too that the aeration system of the plant could not supply sufficient air to the aeration tanks of treatment System A, the older of the two sections of the treatment plant, to meet exerted oxygen demands. It was demonstrated that the plant was not being adversely affected by toxic materials or even inhibitory substances in the wastewaters as had been hypothesized unless, of course, the effects of any toxic materials were masked during the project by the overwhelming impact on the plant of the hydraulic and organic overloads and the inadequacy of the aeration system of treatment System A. Moreover, it was learned that a filamentous sulfur organism existed in great numbers among the biota of the plant prior to the execution of the project pretreatment studies and created a poorly settling activated sludge and that this organism could be destroyed through aeration of the raw wastewaters and the settling characteristics of the activated sludge of plant thereby improved. In addition, it was shown that preaeration eliminated H_2S formation in the primary tanks, keeping the raw wastewaters "sweet," and minimized it in the aeration basins under slug organic loading conditions and that, under high flow conditions, pretreatment by plain aeration, by aeration with addition of waste activated sludge, and by chlorination was well as perhaps by ammonia addition improved plant performance. Finally, the project indicated that pretreatment by sodium nitrate addition may lead to the occurrence of appreciable denitrification in the primary tanks, causing there a rising sludge problem and to the appearance in the biomass of a witherto unidentified filamentous bacterium that can markedly increase the bulkiness of the biologically active sludge.

In summary, the project, through the application of its pretreatment schemes, significantly improved the performance of the treatment plant under dry-weather conditions by: (1) markedly reducing H_2S production, (2) allowing higher mixed liquor suspended solids levels to be carried without the fear of frequent odor formation, (3) decreasing the bulkiness of the biological floc and consequently the concentration of suspended solids in the final plant effluent, and (4) increasing considerably BOD_5 and COD removals. Furthermore, the project resulted in the development of specific recommendations affecting the operation of the treatment plant. These recommendations were: (1) stormwater inflows into the city's sanitary sewerage system should be reduced appreciably, (2) the performance of the air diffusion systems of the aeration tanks of treatment System A of the sewage treatment plant should be improved, (3) the performance of the anaerobic digesters of the plant should be upgraded, (4) a sound treatment plant preventive maintenance program should be established and implemented, and (5) the batch discharge into the sanitary sewerage system of high pollutional strength and otherwise noxious materials by industries should be prohibited. A further project recommendation was that industries currently practicing batch waste discharging should be strongly encouraged to install waste flow equalization tanks.

B. Subsequent Work

Shortly after the final operational study of the research project was concluded, the city undertook the carrying out of the above-mentioned recommended actions. The aeration tanks of System A were dewatered one at a time to discover why it was so difficult to drive air into these tanks. It was discovered that almost half of the carborundum air diffusers in the system had been removed, (probably at one time or another because they had become clogged or broken) and the air header plugged. The city, subsequently, replaced all the missing as well as the remaining carborundum diffuser elements in both Systems A and B with new "sock" type fine bubble diffuser elements and supplemented the air supply of System A with surplus air from the pretreatment facility. In addition, the city requested Breakstone Foods to proceed with its planned installation of a waste flow equalization tank at the company's Hagerstown cheese plant, a request with which the industry quickly complied. Moreover, the city continued and expanded further the industrial waste survey begun under the project, requesting improvements in the waste disposal practices of other industrial plants, and undertook an ambitious program to abate stormwater inflow and infiltration in its sewer lines, and continued the pretreatment of the incoming wastewaters using aeration with waste activated sludge addition.

As a direct result of the changes made in the aeration systems of the plant, the application of the pretreatment method of preaeration with waste activated sludge addition, and the installation by Breakstone Foods of a flow equalization tank, plant performance improved remarkably (3). For October and November 1971, the monthly averages of daily percent BOD_5 removals were 92% and 94%, respectively. However, plant performance dropped off during the months of January and February 1972, evidently as a result of the reoccurrence of high wet-weather flows. But, the plant still achieved 87% and 88% BOD_5 removals for these months, respectively. Thus, it is anticipated that when stormwater flows in the sewerage system are substantially reduced, the treatment plant should be able to achieve consistently a fairly high degree of wastewater treatment.

SECTION VIII

REFERENCES

1. Wrigley, L.E., "Hagerstown, Maryland, Water Pollution Control Plant," Unpublished report presented to the Hagerstown City Council, Hagerstown, Md. (January 1967).

2. "Anaerobic Sludge Digestion," Manual of Practice No. 16, Water Pollution Control Federation, Washington, D.C. (1968).

3. Barnhart, E., Private communication, Hagerstown, Md. (May 1972).